VERTEBRATE - ZOÖLOGY

PRATT

A COURSE IN

VERTEBRATE ZOÖLOGY

A GUIDE TO THE
DISSECTION AND COMPARATIVE STUDY
OF VERTEBRATE ANIMALS

BY

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PREFACE

The plan of this course is similar to that of the *Invertebrate Zoölogy* published by the author three years ago. Its principal aim is to furnish a guide to the dissection of types of the most important groups of vertebrates. The directions are practical in character and are designed to be in sufficient detail to enable the student to carry on his work intelligently and profitably, and with the least possible waste of time and material. Vertebrates are large animals with complex systems of organs, and it is impossible for a young student to dissect them in the best manner unless he receive full instructions at every important step; — to give such instructions is the main purpose of this book.

The course also seeks to keep the morphological relations of the various organs and systems of organs constantly before the mind, and to make the study a comparative one.

Each of the dissections is complete in itself and is not dependent upon any of the others. The teacher may thus give his class such of the dissections as he wishes, and in the order he wishes.

The directions do not contain exhaustive descriptions of the animals dissected, the completeness of the description in each case being made dependent upon the pedagogical ends aimed at, and upon the time ordinarily at the disposal of the student. The organs which have been treated in the least detail are the muscles, in most cases only the superficial ones being described, and they not minutely. A teacher will find it an easy matter, however, to extend the study of the muscles if he wishes. The particular order in which the various systems of organs of each animal are studied is the one which experience has shown will accomplish the desired result with the greatest economy of time and material.

The number of specimens necessary for a complete dissection is mentioned at the beginning of each description. In most cases one specimen is needed for a study of the outer form and the viscera, including the heart and its principal vessels, one specimen for the complete dissection of the blood vessels, and one for the skeleton. In case material is scarce or expensive, however, the study can always be abbreviated and the most important organs be studied with a single specimen. On the other hand, if material be abundant, it will often be convenient to use more than the number of specimens mentioned.

The author recognizes the great importance as well as the great difficulty of rendering a book of this kind free from errors, and has sought to accomplish this result as nearly as possible. To all who have assisted and advised him he returns hearty thanks; especially to Professor Karl Heider, of the University of Innsbruck, in whose laboratory the greater part of the book was written. He will also be under the greatest obligation to teachers and students who will tell him of any mistakes of fact they may find, or of improvements which may suggest themselves to them.

H. S. PRATT

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INTRODUCTION

Apparatus. Each student should be provided with the following instruments: two scalpels, — a small one and one of medium size; two pairs of scissors, — a large straight pair, and a small pair preferably with curved tips; two pairs of forceps, — a small and a large pair, both straight and with corrugated tips; two dissecting needles, a probe, a blowpipe, and a hand lens. There should also be in the laboratory at the disposal of the class one or more large scalpels, a pair of bone cutters, a small saw, and materials for making injections.

Each student should have a large dissecting pan — in the bottom of which is a layer of black wax — and a dissecting board. He should also have a number of strong pins, which may be conveniently kept, while not in use, stuck in a large cork.

Dissecting and drawing. Skill in dissecting is usually quickly acquired with practice. The student should bear in mind that dissection does not mean cutting and slashing, but the careful separation of parts in order that they may be studied. He should do this without cutting, when possible, and when he does use the scalpel and scissors he should do it slowly and carefully, and always know exactly what he is about. It is also important that the scalpel, forceps, and needle be held between the thumb and the first and second fingers, like a pen, — except when a good deal of force must be exerted.

The drawings must be clear and neat; they should be more or less diagrammatic, and should be made with a hard drawing pencil in a large blank book, the paper of which is firm and strong, or on drawing paper. Previous training in drawing is not necessary, as the principal object of the drawings is to show accurately the relations of the various parts to one another, and not to make pictures. Shading should usually not be done, and

all the lines should be firm and definite. The use of colors is often helpful in drawing complex figures, although not necessary; but in case of their use great care should be taken that they be neatly put on, as the careless use of colors invariably injures the drawing.

Anatomical terms. No particular system of anatomical nomenclature has been employed in this book, such terms being used as would make the descriptions exact, and easy to understand. *Anterior* and *posterior* indicate the direction toward the front and hind ends of the body, respectively; *dorsal*, the direction toward the upper side, and *ventral* that toward the under side. *Lateral* indicates the direction away from the middle, longitudinal plane of the body, and *medial* the direction toward that plane. *Proximal* and *distal* are usually applied to portions of an extremity or projection, and indicate the direction toward and away from its base or attached end, respectively. A *dorsoventral plane* passes between the upper and the under surfaces of the body,—the *sagittal plane* being the median, longitudinal, dorsoventral plane.

Materials for dissection. The dogfish and skate may be obtained, already injected if desired, from Dr. F. H. Lambert, Tufts College, Massachusetts, or from the Supply Department of the Biological Laboratory, Woods Hole, Massachusetts. The perch can be caught in any fresh-water stream or pond; it can also be purchased of Brimley Bros., Raleigh, North Carolina, and often at fish markets. Necturus can be obtained of Alexander Nielsen, Venice, Ohio, at 10 cents apiece. Frogs are easily obtained, except in the winter, in marshes and ponds, or they can be purchased of Brimley Bros. Turtles may be caught with a small net in ponds, and can be purchased in the fish markets of the larger cities: Upperman Bros., 1207 Filbert Street, Philadelphia, will furnish them. Birds and cats are always easy to obtain.

Books for reference. It is very important that the laboratory be supplied with text-books of comparative anatomy, and that the dissections be supplemented by constant reference to them, and by lectures and recitations. The two best text-books in English are Kingsley's *Text-Book of Vertebrate Zoölogy* (Holt) and Wiedersheim's *Elements of the Comparative Anatomy of*

Vertebrates (Macmillan). The former treats the subject from the standpoint of embryology, the latter from that of the adult structure. The former has the advantage of being an American book in which American animals are used by way of illustration wherever possible, and also of containing an extended outline of the classification of vertebrates.

More exhaustive works on the comparative anatomy of vertebrates are Gegenbaur's *Vergleichende Anatomie der Wirbelthiere* (Engelmann) and Owen's *Comparative Anatomy and Physiology of Vertebrates* (Longmans, Green & Co., 1866).

The dogfish is described in Marshall and Hurst's *Practical Zoölogy* (Black), Parker's *Elementary Biology* (Macmillan), and Parker and Parker's *Practical Zoölogy* (Macmillan). The skate is described in Parker's *Zoötomy* (Macmillan). The perch is described in Vogt and Yung's *Vergleichende Anatomie* (Vieweg). In Parker's *Zoötomy* a description of the cod is given. Necturus is not described in any text-book. The frog is described in many. The best descriptive work is Gaupp's *Anatomie des Frosches* (Vieweg). Extended descriptions are also found in Huxley and Martin's *Practical Biology* (Macmillan), Parker and Parker's *Practical Zoölogy*, and Marshall's *Anatomy of the Frog* (Black). Extended descriptions of the turtle and the pigeon are found in Martin and Moale's *How to dissect a Chelonian* and *How to dissect a Bird* (Macmillan). A description of the pigeon is also found in Marshall and Hurst's *Practical Zoölogy* and in Parker's *Zoötomy*. The cat is completely described in Reighard and Jenning's *Anatomy of the Cat* (Holt); less extended descriptions will be found in Wilder and Gage's *Anatomical Technology* (Comstock), *Mivart's Cat* (Macmillan), and Davison's *Mammalian Anatomy* (Blakiston).

The best of the larger general text-books of zoölogy are Hertwig's *Manual of Zoölogy*, translated by Kingsley (Holt), Parker and Haswell's *Text-Book of Zoölogy* (Macmillan), and Weysse's *Synoptic Text-Book of Zoölogy* (Macmillan). The portion of Hertwig's *Zoölogy* treating of vertebrates is especially good, and gives a résumé of their comparative anatomy and classification.

Classification of vertebrates. The following classification has been taken, with some modifications, from Wiedersheim's *Comparative Anatomy.*

I. Ichthyopsida: vertebrates breathing through gills either a part or all of their lives.
  A. Cyclostomata: suctorial fishes, without jaws or paired fins.
    1. Petromyzontidæ: lampreys.
    2. Myxinoidæ: hag fishes.
  B. Gnathostomata: true jaws present.
    1. Pisces: fishes with paired fins.
      (*a*) Elasmobranchii: cartilaginous fishes; sharks and skates.
      (*b*) Ganoidei: sturgeons, garpikes, etc.
      (*c*) Dipnoi: lung fishes.
      (*d*) Teleostei: bony fishes; the common fishes.
    2. Amphibia: amphibians; batrachians.
      (*a*) Urodela: tailed amphibians; salamanders.
      (*b*) Anura: tailless amphibians; frogs and toads.
      (*c*) Gymnophiona: limbless amphibians.

II. Sauropsida: vertebrates never breathing through gills, with one occipital condyle.
    1. Reptilia: reptiles.
      (*a*) Crocodilia: crocodiles and alligators.
      (*b*) Lacertilia: lizards.
      (*c*) Chelonia: turtles.
      (*d*) Ophidia: snakes.
    2. Aves: birds.

III. Mammalia: vertebrates which suckle their young.

VERTEBRATE ZOÖLOGY

CHAPTER I

FISHES

AN ELASMOBRANCHIAN FISH. THE DOGFISH

Several species of dogfish are common along the Atlantic coast. They are the smallest of the sharks, and feed upon other fishes, crustaceans, mollusks, and upon carrion. The species which have been used as the basis of this dissection are *Mustelus canis* and *Squalus acanthias*. The latter animal is easily distinguished from the former by the prominent spine which projects from the anterior border of each dorsal fin.

For purposes of dissection, however, any species of dogfish will do as well as either of these. The common skate may also be used; it is a near relative of the dogfish, and although in external form and appearance it is very different from that fish, in internal structure it differs very little. The main point of difference is the structure of the pectoral fins, which in the skate are enormously developed and are attached to the side of the body along almost its whole length.

Three specimens will be needed for a complete dissection: one for the external form and the principal viscera, including the heart, the brain, and the nerves; one for the blood vessels; and one for the skeleton. During the progress of the dissection the specimens should be kept in a five per cent solution of formalin.

The body of the dogfish is much elongated and nearly cylindrical. The head is dorsoventrally depressed, with a projecting snout and a slitlike mouth on its ventral side. The hinder end of the body is laterally compressed, and terminates with a slender tail, which is the principal organ of locomotion.

The entire body, including the fins and the tail, is covered with minute **placoid scales**. Note in which direction their sharp points project. With the aid of a hand lens examine the scales at different parts of the body: they differ in size at different places, being larger on the dorsal than on the ventral surface. In the neighborhood of the mouth they have lost their sharp points. Note that they pass over the lips into the mouth and are continuous with the teeth; note also that they are arranged in diagonal rows. Along each side of the body will be seen the **lateral line**, — a straight line which extends the length of the body: it is an organ of special sense.

Note the color of the animal and the variation of color at different parts of the body.

The body of the dogfish may be divided into three regions, — the **head**, the **trunk**, and the **tail**. There is no neck.

The head and the trunk. The anterior end of the body is flattened and bluntly pointed. On its lateral surface are the elongated **eyes**, each with two lids, the lower one of which can be moved over the eye. In Mustelus, in addition to these, a third lid, the **nictitating membrane**, is present: it is a translucent membrane which can be drawn from the inner corner of the eye across it. Back of the eyes on each side are six prominent openings, all of which communicate with the pharynx: these are the **spiracle**, which is just back of the posterior corner of the eye, and the five **gill slits**, just in front of the anterior fins. The spiracle is homologous to a gill slit; its function is to act as a means of ingress for the respiratory water. The gill slits contain the gills, — the organs of respiration. The respiratory water passes into the cavity of the mouth and pharynx through the mouth and spiracles, and out again through the gill slits, bathing the gills on its way.

Note the minute openings of the **mucous canals** distributed over the head, which appear as fine points from which mucous can be squeezed: they are sense organs.

On the under side is the crescentic **mouth**, armed with several rows of **teeth**. In Mustelus the teeth are flat and platelike; in Squalus they are sharp. The **nostrils** are a pair of irregular

openings in front of the mouth. In the skate and in some dogfishes each nostril is connected with the mouth by a groove. Probe the nostrils and determine that they are blind sacs and have no communication with the mouth cavity. Distributed over the ventral surface are the ventral **mucous canals.**

The fins, or appendages. Two kinds of fins are present, — **paired fins** and **median fins.** The latter are the more primitive structures and are alone present in the lowest fishes; they are simply dorsal and ventral flattened projections of the body. In Mustelus there are two dorsal fins, one ventral or anal fin, and a heterocercal caudal fin, the latter being both dorsal and ventral. In Squalus each dorsal fin is provided with a sharp spine, and no ventral fin is present.

The **paired fins** are horizontal, flattened projections extending from the latero-ventral surface of the trunk; they are homologous to the extremities of the higher vertebrates. Two pairs are present, — an anterior pair, the **pectoral fins,** and a posterior pair, the **pelvic fins**; each is supported by a cartilaginous arch within the body wall called the **pectoral girdle** and the **pelvic girdle,** respectively. They are easily felt through the skin. In the male the pelvic fins are much longer than in the female; the inner border of each is more or less separated from the remainder and forms a long, rodlike extension backwards. This is called the **clasper** and is of use when the animals mate; observe its structure.

The pelvic fins lie close together and inclose a large median opening, the **anus**: this is the outlet of the **cloaca,** a wide, shallow space which receives the discharges of the digestive and urogenital organs. A pair of small, slitlike passages, called **abdominal pores,** one of which is on each side of the cloaca just within its lateral border, forms a means of communication between the abdominal cavity and the outside; their function is unknown. Probe them. Just in front of these pores is a conical median projection. This is the **urogenital papilla** in the male, and contains the outlet of the urogenital organs, and in the female the **urinary papilla,** which contains only the outlet of the kidneys. The genital opening in the female is just in front of the papilla.

At the front end of the cloaca is the opening of the **rectum**, the hinder end of the digestive tract. The head of the animal extends back to the first gill slit; the anus forms the boundary between the trunk and the tail.

Exercise 1. Draw a side view of the animal and label all of the various organs.

Exercise 2. Draw a dorsal view of the head, showing the distribution of the mucous canals.

Exercise 3. Draw a ventral view of the head, showing the mucous canals and the other features.

The internal organs. Determine the exact location of the pectoral and pelvic girdles, which support the fins of the same name. Make an incision through the body wall in the mid-ventral line from the pectoral girdle to the pelvic girdle; then continue the incision straight through the pelvic girdle to a point immediately in front of the anus, taking care not to cut too deeply. Just back of the pectoral girdle make a transverse incision in each side of the body wall; make similar incisions in front of the pelvic girdle. Place the animal on its back, with its head away from you, on a dissecting board or in a large dissecting pan. Pin down the two flaps of the body wall firmly to the right and left, and thus expose the organs which lie in the abdominal cavity.

Study the position of these organs, but without disturbing them. The entire body cavity is divided by a vertical partition into two chambers, — the small **pericardial chamber** at the anterior end between the gills, in which lies the heart, and the large **abdominal chamber**, which contains the greater part of the viscera; the pericardial chamber has not yet been opened. These cavities are lined by a serous membrane which is called the **pericardium** in the pericardial chamber, and the **peritoneum** in the abdominal chamber. The partition separating these chambers is situated just beneath the pectoral girdle, and is called the **false diaphragm.**

In the forward part of the abdominal chamber is the large yellowish or greenish **liver**; it is composed of two principal lobes which meet in front and are attached to the false diaphragm by a mesentery. Beneath and between the lobes of the liver lie the **stomach** and the **intestine**. The latter is a large tube which proceeds directly back to the cloaca. The former is a bent V-shaped tube in the forward and middle portions of the abdominal chamber, which extends forward beneath (dorsal to) the liver to the anterior end of the cavity. In Squalus it consists of two distinct portions, — a thick, straight, anterior portion and a V-shaped portion, which are separated from each other by a prominent constriction. Note the membranous mesentery which unites the two limbs of the stomach. Attached to the bend of the stomach by a mesentery, and extending back of it, is the large, dark-colored **spleen**. At the point where the intestine leaves the stomach will be seen a portion of the whitish **pancreas**. Note the **gall bladder** imbedded in the liver.

By pushing aside these organs, but not cutting them, the urogenital organs will be seen lying against the dorsal wall of the body cavity. If the animal be not yet adult, the **genital glands** (the testes or the ovaries) will appear as a pair of elongated bodies of greater or less size, but usually an inch or two in length, extending back from the forward end of the abdominal cavity. The dogfish which are bought for dissection are usually immature, and the genital glands and ducts are often too small to be studied.

If the animal be an adult male (and the sex may be determined by the presence or absence of the claspers), the **testes** will appear as a pair of elongated, flattened bodies, supported by mesenteries. If the animal be an adult female, the **ovaries** will be seen, — irregular, elongated bodies, usually with yellow spherical ova projecting from the surface. The **oviducts** are a pair of large tubes lying against the dorsal wall of the abdominal cavity, at the forward end of which their anterior ends fuse ; a single median opening is present here on the ventral side of the fused ends, through which the ova find their way into the oviducts from the abdominal cavity. The extreme

posterior ends of the oviducts join each other and open into the cloaca by a large pore just in front of the urinary papilla.

Exercise 4. Draw an outline of the abdominal cavity and the organs which appear in the ventral aspect.

The pericardial cavity and the heart. The organs just examined lie in the abdominal cavity; the pericardial cavity contains the **heart**. This organ in fishes stands in close relation to the gills and lies in the midventral plane between them.

Cut away the skin covering the median portion of the pectoral girdle and the interbranchial muscles just in front of it. Cut away and remove the girdle and the muscles and expose the pericardial chamber. Study the heart, which lies in it.

Note the shape of the pericardial chamber. Note also that its posterior wall lies against the anterior wall of the abdominal chamber, and that the two walls form the false diaphragm. The **heart** consists of a single **ventricle**, which is a muscular organ occupying a large part of the pericardial chamber; a single **auricle**, which is the large, triangular, thin-walled sac lying dorsal to (back of) the ventricle, and appearing at its sides; a **conus arteriosus**, a muscular, cylindrical prolongation of the anterior end of the ventricle; and the **sinus venosus**, a thin-walled tube stretching transversely across the hinder part of the pericardial chamber, to the dorsal wall of which it is attached. The sinus will be seen by pressing the ventricle forward or lifting it a little. Blood is brought from the tissues and organs of the body to the sinus venosus, from which it enters the auricle. From this vessel it is transferred to the ventricle, by which it is pumped through the conus arteriosus to the gills. The heart contains only venous blood.

The pericardial cavity is placed in communication with the abdominal cavity by a median canal, the **pericardio-peritoneal canal.** This is a passage which opens into the pericardial cavity by a large pore back of the sinus venosus, and into the abdominal cavity back of the œsophagus.

Exercise 5. Draw an outline of the ventral aspect of the pericardial cavity and the organs in it.

The inner structure of the heart. Cut open the ventricle and conus arteriosus by a lateral incision carried along the left side of both. Turn the flap, which will constitute the entire ventral wall of the heart, to one side, exposing its interior; wash this out thoroughly. The ventricle will be seen to be a thick-walled vessel with a small central cavity. Note the muscle ridges on its inner surface. In its dorsal wall is a large opening by which the auricle communicates with it. Blow into this **auriculo-ventricular opening** with a blowpipe.

Attached to the wall of the conus arteriosus are six small pocketlike valves arranged in two rows, which permit the blood to flow away from the heart only. Bring them into view by means of the blowpipe; note the direction in which they act.

Fill the auricle with air by blowing into it through the auriculo-ventricular opening. Open the auricle by a lateral incision and wash it out. Note its thin walls and its large cavity. With the blowpipe find the opening into the sinus venosus.

Exercise 6. Draw a view of the opened ventricle and conus arteriosus, showing the muscle ridges, the valves, and the openings.

The pharynx and the mouth. Insert one blade of the scissors in the corner of the mouth on the left side, and carry a cut straight back across the gills as far as the pectoral girdle. From the end of this incision carry another across the floor of the pharynx, just back of the heart, to the opposite side of the body. Turn the flap thus formed, which is the entire ventral side of the head, over to the animal's right and pin it there, exposing the cavity of the mouth and pharynx.

These two cavities will be seen to form a single large space, bounded in front by the opening of the mouth and behind by the beginning of the gullet or œsophagus. The whole is lined by a slightly folded mucous membrane. On each side the body wall is pierced by six large clefts, of which the five posterior are the **gill slits**, and the anterior one is the **spiracle**. Probe these

clefts. Examine the gills in the gill slits, and the cartilaginous gill arches which support them. Note that the hinder wall of the last gill slit is without a gill. The spiracle is homologous to a gill slit and may contain a rudimentary gill. Slit it open and examine its walls.

On the ventral side is the prominent **tongue**, supported by the hyoid cartilages beneath the mucous membrane. Feel these cartilages with the fingers.

Observe the character and arrangement of the teeth in both upper and lower jaw. In Squalus they are sharp, as in the majority of sharks; in Mustelus they have lost their sharp points and are reduced to flat plates.

Exercise 7. Draw a semidiagrammatic sketch of both dorsal and ventral walls of the mouth and pharynx.

Cut two or three gill arches from the body. Note that each gill is composed of two rows of **gill filaments**, an anterior and a posterior row, and that each gill slit is bounded on the one side by the posterior filaments of one gill, and on the opposite side by the anterior filaments of the gill next back of it. The gills in fishes are outgrowths of the wall of the pharynx.

Exercise 8. Draw a gill slit and the filaments bounding it.

The digestive system. This system consists of the mouth, pharynx, œsophagus, stomach, intestine, cloaca, and the three intestinal glands, — the liver, pancreas, and rectal gland.

(Cut the mesentery which attaches the spleen to the stomach, and remove the spleen from the body.) Joining the median portion of the liver with the anterior end of the intestine is a large tubular vessel, the **bile duct**, alongside which are the hepatic artery and the portal vein; they must not be cut. Note the wide **mesentery** which joins the stomach and the anterior end of the intestine with the dorsal body wall; and also the mesentery which joins the two limbs of the V-shaped stomach.

Lift up the stomach and intestine and observe the whitish **pancreas**; carefully note its shape and position. Find the **pancreatic duct**: it is a small tube which leaves the pancreas near

its anterior end and enters the ventral wall of the intestine, which it traverses a short distance.

Note that the hinder portion of the intestine is not joined with the dorsal body wall by a mesentery, except at its extreme hinder end. Note the elongated, cylindrical **rectal gland**, which lies in this mesentery. Find the **duct** which joins it with the rectum.

Observe again the large **stomach**. The anterior end passes forward beneath the liver and is joined with the pharynx by a very short and equally thick œsophagus. Pass a probe from the pharynx into the stomach. The anterior end of the stomach is called the **cardiac end**. The posterior V-shaped portion of the stomach is continuous with the intestine, the posterior end of it being called the **pyloric end**.

Trace the bile duct from the liver to its point of union with the intestine, which is a short distance posterior to the pylorus.

The **intestine** is made up of three portions, — the duodenum, colon, and rectum. The **duodenum** is very short and forms the anterior end of the intestine; it receives the bile duct. The **colon** forms the principal portion of the intestine and is characterized by the presence in it of an extensive spiral fold of the mucous membrane, called the **spiral valve**. This fold extends from the inner wall of the intestine and almost fills it; its attachment to the intestinal wall is plainly seen on the outside. The **rectum** is short and extends from the colon to the cloaca. It is joined by a short duct from the rectal gland.

Exercise 9. Draw a semidiagrammatic sketch of the digestive system. Represent accurately the shape of the liver and the pancreas, and the bile and pancreatic ducts. Carefully label all.

Study the **spiral valve**. Make a longitudinal slit in the ventral wall of the colon and duodenum. The spiral valve will be seen to be a wide fold which extends into the cavity of the colon from its inner surface, forming a series of spirals nearly filling it. They have the appearance of a nest of elongated cones, one inside the other, and opening backward. (Beginning at its hinder

end, cut the spiral valve from the intestinal wall with scissors. It will be seen to be a single fold.|

The function of the spiral valve is to increase the intestinal surface.

Exercise 10. Draw a diagram of the spiral valve.

Slit open the entire stomach and note the folds in its mucous membrane.

The urogenital system. The urinary and the genital organs are closely associated with each other and will be studied together. (Entirely remove the digestive system from the body.) (In an immature animal the genital organs cannot be studied. |

The **genital organs** consist of the **genital glands**, which are the paired **testes** or **ovaries**, and the paired **excurrent canals**, which in the female are the very large oviducts. The testes or ovaries, as we have already seen, are soft, elongated bodies at the forward end of the abdominal cavity and attached to the dorsal body wall by mesenteries. In Mustelus the two genital glands are grown together.

The **urinary organs** are composed of the paired **kidneys** and the paired **excurrent canals**. The kidneys are narrow, elongated organs which lie, one on each side of the median line, close against the dorsal body wall and covered ventrally by the peritoneum; they extend almost the entire length of the abdominal cavity. In the male the anterior half of each kidney loses its excretory function and enters into a close relation with the testis.

The excurrent canals of the kidneys are called the **Wolffian ducts**. They differ considerably in the two sexes, in the male acting also as the excurrent ducts of the testes. The male Wolffian duct on each side begins at the forward end of the kidney, appearing as a very much convoluted tube on the ventral side of it, and passes to the hinder part of the abdominal cavity. Here it joins the other Wolffian duct, and the median vessel thus formed opens into the cloaca at the end of the urogenital papilla, just behind the opening of the rectum.

The anterior and posterior portions of this duct are very distinct from each other. The anterior convoluted portion, which

is called the **epididymis**, is exclusively a sperm duct, and does not carry urine. At its anterior end it is connected by means of delicate tubes, called the **vasa efferentia**, with the anterior end of the testis, from which it receives sperm. The posterior portion is not convoluted, and its hinder end is enlarged to form a seminal vesicle. Through this portion the sperm is brought from the epididymis to the cloaca; it also acts as a ureter, a number of urinary tubes arising from the kidney and proceeding to its hinder end. The Wolffian duct thus acts both as a vas deferens, or sperm duct, and as a ureter, and on account of this double function is also called the **duct of Leydig**.

In the female animal the Wolffian duct is exclusively a ureter, corresponding to the hinder part only of the same duct in the male, and receives a number of urinary tubes from different parts of the kidney. The two Wolffian ducts meet at their hinder ends, and the median vessel thus formed opens into the cloaca at the end of the urinary papilla, behind the rectum.

The excurrent canals of the genital organs in the female are called the **Müllerian ducts**, or **oviducts**; they are not present in the male, except sometimes as rudiments. They are a pair of large tubes which extend the entire length of the abdominal cavity. Their anterior ends are joined, and open into the abdominal cavity by a large median pore which is situated just in front of the liver and beneath the œsophagus. In the anterior part of each oviduct is the large, ovoid **shell gland**; in its posterior part is the wide, distended **uterus**.

The ova are thrown into the abdominal cavity by the rupture of the walls of the ovaries. They pass into the oviducts through the median pore just mentioned, where they are fertilized. They remain in the uterus, in Squalus and Mustelus, while development takes place, the young animals being born alive; in many other sharks which are oviparous a characteristic black, horny shell is formed in the uterus.

Exercise 11. Make a semidiagrammatic drawing of the urogenital system, so far as observed, together with the cloaca.

The nervous system. This is made up of three groups of organs: (1) the **central nervous system,** which includes the brain and the spinal cord; (2) the **peripheral nervous system,** which includes the paired cranial and spinal nerves by which the brain and the spinal cord are placed in connection with the various organs of the body, and the sympathetic nervous system whose function is to innervate the important viscera of the body cavity; and (3) the **special sense organs,** by which the animal is placed in touch with its environment. We shall study the last-named organs first.

The **special sense organs** include the integumental sense organs, the olfactory organs, the eyes, and the ears.

The integumental sense organs. Imbedded in the skin of the fish are minute sense buds whose exact function is not known, but which undoubtedly enable the animal to receive certain impressions from the water surrounding it. The most important of these in the dogfish are the **lateral line** and the **ampullæ of Lorenzini.**[1]

The **lateral line** is a canal in the integument which extends along each side of the body from the head to the hinder end; it appears on the outer surface as a light-colored ridge. In this canal are groups of sensory cells which are innervated by the tenth cranial nerve. Each of these groups has a minute opening to the outside. The lateral line also extends on to the head, but is here difficult to see in an ordinary dissection.

The **ampullæ of Lorenzini** are bulb-shaped bodies at the end of long mucous canals, which open upon the head, and are most numerous on the snout. The external openings of these canals appear as dots upon the skin; the canals are filled with a transparent secretion. The ampullæ are collected in three principal groups, the largest of which is on the under surface of the anterior end of the snout, while the other two are on the side of the head in front of and between the eyes. From these points the canals proceed to the external openings, which are arranged in rows on the head, and vary, consequently, a good deal in length, some of them measuring an inch or more.

[1] See "The Function of the Lateral-Line Organs in Fishes," by G. H. Parker, in *Bulletin of Bureau of Fisheries for 1904*, Vol. XXIV, p. 183.

Observe the openings of these canals. Skin the anterior portion of the head and study the arrangement of the canals, tracing them to their ends.

The olfactory organ. Two nasal capsules are present, which open to the outside on the ventral surface of the snout, in front of the mouth. Remove the ventral wall of one of these and dissect the capsule from the body. Note its large size and its connection with the olfactory nerves. Cut it open and note the folds in its mucous membrane, and their arrangement.

Exercise 12. Draw the nasal capsule.

The eyes. Cut away the eyelids of the right eye and the cartilaginous ridge of the skull which surrounds it, so as to expose thoroughly the orbit. Study the **eyeball** as it lies in the orbit. The white **pupil**, which is an opening admitting light into the inner part of the eye, will be seen; surrounding the pupil is the black **iris**, and covering both and forming the outer coating of the front of the eye is the transparent **cornea.** At the back and sides of the eyeball the outer coating is called the **sclera.** A transparent membrane called the **conjunctiva**, which is continuous with the inner lining of the eyelid, passes over the front of the eye.

Exercise 13. Draw the front aspect of the eyeball.

The eyeball is hemispherical in shape, the front surface, the cornea, being flattened. Press the eyeball medially and note the broad, bandlike nerve which lies across the inner part of the orbit, dividing into two branches near its outer edge.

The **muscles** of the eyeball, by means of which its position in the socket can be changed, are six in number. Press the eyeball downwards and note on its medial side two muscles which are inserted close together. The anterior one is the **superior oblique muscle**, which goes to the inner anterior wall of the orbit; the posterior one is the **superior rectus muscle**, which goes to the inner posterior wall of the orbit. Note the white nerve strands; they may be distinguished from the muscles by their whiteness.

Press the eyeball backward and medially and note the **inferior oblique muscle**, which has its insertion on the antero-ventral side of it and goes to the inner anterior wall of the orbit. On the posterior side of the eyeball is the **external rectus muscle**, which goes to the hinder wall of the orbit. Cut the superior oblique muscle at its insertion in the eyeball; beneath and in front of it will be seen the **internal rectus muscle**, which runs back to the hinder wall of the orbit. Cut all of these muscles at their insertion on the eyeball and pull it gently forward; the **inferior rectus muscle** will be seen, which passes from the lower side of the eyeball to the posterior wall of the orbit.

Find the **optic nerve**; it will be seen to enter the eyeball. Cut the nerve and remove the eyeball from the orbit. Note the origins of the six eye muscles in the orbit; the two oblique muscles will be seen to take their origin in its anterior wall, and the four rectus muscles in its posterior wall.

Study the structure of the eyeball. Its outer wall is made up of three layers, which are called the **sclera**, or **sclerotic coat**, the **choroid coat**, and the **retina**. The sclera is the outer coating; it covers the entire eye except in front, where its place is taken by the **cornea**.

Just within the sclera is the choroid coat. Cut the eyeball in two by an incision parallel to the cornea, so that you can look into the interior. The soft **vitreous humor** which forms the inner portion of the eye will exude, and the **crystalline lens** will be seen. The choroid coat will be recognized by its dark color; it contains the pigment of the eye and the blood vessels which supply it. On the inner surface of the choroid, next to the retina, is a layer called the **tapetum lucidum**, which reflects light and causes the eye to shine in the dark.

Just within the choroid and forming the inner lining of the eye is the **retina**; it is light in color and is easily separated from the choroid.

The retina represents an expansion of the optic nerve on the inner surface of the eye, and is the portion of it which is sensitive to light. Note the point where the optic nerve pierces the sclera and choroid; this point is called the **blind spot** because it

is nonsensitive. Projecting from the inner surface of the eye very near the blind spot is a slender rod called the **processus falciformis**; it ends in an enlargement called the **campanula Halleri,** which rests against the lens. The campanula is composed mainly of smooth muscle fibers by the action of which the position of the lens is slightly changed and a certain degree of accommodation is effected. A ciliary apparatus, which is the principal organ of accommodation in the eyes of the higher vertebrates, is not present.

The eye has in it two principal chambers, — an anterior chamber between the iris and the cornea, which is filled with a watery fluid called the **aqueous humor,** and a large posterior chamber which is filled with the gelatinous **vitreous humor.**

Exercise 14. Draw a diagram showing the position of the muscles of the eyeball.

Exercise 15. Draw a diagram showing the structure of the eye.

The ear. An internal ear is alone present in fishes, there being no outer ear and no ear opening. The internal ear is a membranous labyrinth, which is inclosed in a cartilaginous capsule situated immediately back of the posterior margin of the orbit on each side. It is made up of a spherical sac, the **vestibule,** from the dorsal surface of which spring three **semicircular canals,** — an anterior vertical, a posterior vertical, and a horizontal canal. Each of these canals has a small swelling at one end called an **ampulla.** From the dorsal surface of the vestibule there also arises a delicate tube, the **endolymphatic duct,** which passes through the roof of the skull to the outer skin, which is here pierced by a small hole. The ear comes into existence in the embryo as an infolding of the outer wall of the head, and this duct is a remnant of this infolding.

The membranous labyrinth is extremely delicate and is difficult to dissect. With care and patience, however, this may be done; the semicircular canals, at least, should be found. Remove the skin and muscles completely from the top of the

head back of the eye on the right side. A ridge will be seen in the roof of the skull extending backward from the orbit. Within this ridge and immediately beneath its cartilaginous wall is the anterior vertical semicircular canal. Very carefully shave off the roof of the ridge and find it; it will be seen to have the diameter of a fine needle. Just back of it is the posterior vertical canal. Lying between the hinder end of this canal and the orbit in the cartilage is the horizontal canal. Note the ampulla of each of these canals. Beneath them is the vestibule.

In most fishes the ear has no auditory function, but is an organ of equilibrium.

Exercise 16. Draw the membranous labyrinth so far as observed.

The central nervous system. Remove the skin and muscles from the dorsal surface of the head. Very carefully shave off the roof of the skull and expose the dorsal surface of the **brain**; do not disturb, however, any part of the orbits of the eyes or the nerves in them.

The **brain**, as it appears in a dorsal view, is made up of five divisions,—the cerebrum, thalamencephalon, optic lobes, cerebellum, and medulla oblongata, of which the cerebrum and cerebellum are much more prominent than the other three divisions. The **cerebrum** is the anterior division and is composed of a pair of rather indistinctly marked **hemispheres**, from each of which a large **olfactory lobe** projects forward to the nasal capsule.

The second division, the **thalamencephalon**, is a small area just back of the cerebrum. Its dorsal wall is thin and supports the **pineal body**, a very slender projection which extends forward and dorsally to the skull; it may have been removed with it. The third division, the **optic lobes** or **midbrain**, consists of a pair of rounded bodies back of the thalamencephalon. The fourth division is the **cerebellum**, a prominent, elongated body which extends forward over the posterior portion of the optic lobes and backward over the fifth division; it is divided into several lobes. The fifth division is the **medulla oblongata**; it forms the hinder portion of the brain and is continuous with the spinal cord; in its delicate dorsal wall is a large depression called the **fossa**

rhomboidalis, at the sides of which is a pair of lateral projections, the **restiform bodies.**

Exercise 17. Draw the dorsal aspect of the brain on a scale of 2 or 3; carefully label its parts.

The cranial nerves. Ten pairs of these nerves are present, which, with their most important branches, are the following:

1. The **olfactory nerves.** These nerves form a large group of minute fibers which extend from the anterior end of each olfactory lobe into the nasal capsules. Look for them on the right side of the head; they will be seen by pressing the anterior end of the olfactory lobe back from the wall of the nasal capsule.

2. The **optic nerves** arise on the ventral surface of the thalamencephalon, where they will be seen when the ventral surface of the brain is studied; each passes through a foramen in the orbit to the eye. Press the side of the skull gently from the brain and find them.

3. The **oculomotor** is a small nerve which arises in the ventral surface of the optic lobe on each side and passes laterally to the orbit; it enters the orbit a short distance back of the optic nerve and goes to the inferior rectus, the superior rectus, and the inferior oblique muscles. It may be seen by pressing the side of the skull away from the optic lobes.

4. The **trochlear** or **pathetic nerve** is a delicate strand which arises from the latero-dorsal surface of the brain between the optic lobe and the cerebellum. It runs forward to the orbit, which it enters above the optic nerve, and goes to the superior oblique muscle. It may be seen emerging from beneath the anterior portion of the cerebellum and passing to the orbit.

5. The **trigeminal nerve** arises from the side of the anterior end of the medulla in close connection with the seventh and eighth nerves and opposite the posterior portion of the cerebellum. Cut away the wall of the skull and find these three nerves. The trigeminal nerve has three main branches. (1) The **ophthalmic branch** leaves it almost at its origin and enters the orbit, along the medial side of which it passes to its anterior end;

here it passes out through a foramen and runs forward on the dorsal surface of the snout, where it innervates the Lorenzinian ampullæ. (2) The **maxillary branch** and (3) the **mandibular branch** form the main part of the trigeminal, which enters the orbit as one nerve by a foramen at its hinder end and runs diagonally across the floor of the orbit as a broad band to its outer margin, where it divides into these two branches. They at once emerge from the orbit and go to the Lorenzinian ampullæ. Trace them as far as possible.

6. The **abducens** is a very small nerve which arises from the ventral surface of the medulla near the median line behind the roots of the trigeminal, and passes through the same foramen with this nerve into the orbit to the external rectus muscle. The root of this nerve will be seen when the ventral surface of the brain is studied.

7. The **facial nerve** arises in connection with the trigeminus. It sends out three main branches. (1) The **ophthalmic branch** passes, together with the ophthalmic branch of the trigeminal nerve, along the medial wall of the orbit to the ampullæ of Lorenzini on the snout. (2) The **palatine branch** and (3) the **hyoid branch** form the main part of the facial, which enters the orbit as a single nerve directly back of the trigeminal, and divides into these two branches. The palatine passes across the floor of the orbit parallel with the large trigeminal nerve branch; the hyoid branch runs across the posterior part of the orbit to the spiracle and the hyoid arch.

8. The **auditory nerve** is a large, short nerve which arises in connection with the trigeminal and facial nerves and almost at once enters the auditory capsule. It is the shortest cranial nerve and the only one which remains within the cranium. It may be seen by pressing the wall of the skull away from the brain.

9. The **glossopharyngeal nerve** arises on the side of the medulla some distance back of the auditory nerve. It may be seen by pressing the wall of the skull away from the brain. It at once enters a foramen in the inner wall of the auditory capsule and, passing through the capsule, divides into two branches which go to the hyoid arch and the first gill arch.

10. The **vagus**, or **pneumogastric**, is a large nerve which arises by a number of roots on the side of the medulla near its dorsal surface. It passes out of the skull at once by a foramen back of the auditory capsule and runs back, as a broad band, along the inner side of the gill arches, sending a large branch to each of the hinder four arches. It also gives off, in front of these gill nerves, the **lateral-line nerve**, which passes to the lateral line and runs parallel to it to the hinder end of the body. The main portion of the vagus, after giving off the gill nerves, supplies the heart, stomach, and other organs.

Exercise 18. Draw a side view of the brain, showing the cranial nerves, so far as they have been observed.

The ventral surface of the brain. Remove the two sides of the skull. Separate both olfactory lobes from their capsules and bend the cerebrum back, exposing its ventral surface. Press the side of the brain away from the under portion of the skull and note the small trochlear nerve which issues from the ventral surface of the optic lobe and enters the orbit, and also the small abducens nerve which issues from the medulla and also goes to the orbit. Cut these nerves. Cut the optic nerves and note back of them a pair of lobed bodies, the **lobi inferiores**, between which is a median projection, the **infundibulum**. Extending backward from the infundibulum is the **hypophysis**, or **pituitary body**, which fills a deep depression in the ventral wall of the skull. All of these structures belong to the thalamencephalon. Back of the infundibulum the ventral surface of the brain is without important special structures.

Exercise 19. After removing the brain from the body, draw the ventral aspect on a scale of 2 or 3, and carefully label all the organs observed.

The ventricles of the brain. The brain is a hollow structure and contains a series of spaces which are continuous with the central canal of the spinal cord. In the two hemispheres are two large spaces called the **first** and **second**, or the **lateral, ventricles.** Make a transverse incision across the hemispheres and observe

them. In the thalamencephalon is the **third ventricle**, which joins the first two at its forward end. The roof of the third ventricle is the thin dorsal wall of the thalamencephalon, which has been already mentioned. The **fourth ventricle** is in the medulla, where it occupies the fossa rhomboidalis, the roof of which is also very thin. The third and fourth ventricles are joined by a canal called the **aqueductus Sylvii**; this canal passes between the optic lobes and communicates with the large space in each of them. Bisect the brain and observe these spaces.

Exercise 20. Draw a diagram representing the cavities of the brain.

The vascular system. This system consists of the following organs: (1) the **heart**, the muscular pump which sends venous blood to the gills to be purified; (2) the **arterial system**, which carries (*a*) venous blood from the heart to the gills, and (*b*) arterial blood from the gills to the tissues; (3) the **venous system**, which includes (*a*) the systemic veins, which carry blood directly to the heart, and (*b*) the portal veins, which carry blood directly to the liver and the kidneys, from which organs it passes to the heart; (4) the **capillaries**, the minute vessels by which the blood is distributed in the tissues.

We shall first study the **portal veins**. Two systems of these veins are present, — (1) the **hepatic portal system**, which carries blood from the digestive tract and spleen to the liver, and (2) the **renal portal system**, which carries blood from the hinder portions of the body to the kidneys.

The hepatic portal system. Place the animal on its back with its head away from you, and open the abdominal cavity in the manner already described (see page 4). A large vein will be seen passing from the anterior end of the intestine to the liver, and entering it near the median plane; this is the **hepatic portal vein**. Trace it forward into the liver, on the dorsal surface of which it will be seen to break up into several branches, which go to the different lobes of that organ.

Trace the vein backward; it will be seen to be formed by the union of several large veins from the intestine, stomach,

pancreas, and spleen.[1] Cut the mesentery, where necessary, and determine the course of these veins and their branches.

Exercise 21. Draw a diagram representing the hepatic portal system, including outlines of the liver, stomach, intestine, pancreas, and spleen.

The renal portal system consists of the **caudal vein** and two **renal portal veins.** The former lies in the median line in the tail immediately below the spinal column; it and the dorsal aorta, which lies just above it, are inclosed in the cartilaginous arches of the ventral side of the vertebræ. The caudal vein enters the abdominal cavity at its hinder end and at once divides into a right and a left renal vein, each of which passes to the lateral side of a kidney and sends numerous branches into it along its entire length.

Exercise 22. Draw a diagram of the renal portal system.

The **systemic veins,** which form the main venous system, are characterized by their great size, being in some places so wide that they are called **sinuses.** These veins include a pair of **anterior** and a pair of **posterior cardinal sinuses,** which bring blood from the anterior and posterior parts of the body respectively. The anterior and posterior cardinals on each side meet in a common transverse sinus called the **duct of Cuvier,** which extends from the end of the sinus venosus dorsally and laterally. Opening into the sinus venosus, also, near the median plane is a pair of **hepatic sinuses,** which bring blood from the liver. The cardinal vessels are dorsal in position and the hepatic sinuses are ventral.

Entering the anterior end of the posterior cardinal sinus from behind, on each side, are the **lateral vein** and the **subclavian vein.** The former will be seen extending along the inner surface of the wall of the abdominal cavity from one end of it to the other, opposite the lateral line; the latter lies along the pectoral girdle and brings blood from the pectoral fin. The **iliac vein,**

[1] If the hepatic portal vein be injected, these veins will be made more prominent. They are, however, usually easy to study without injection, because they usually contain blood, which colors them.

which brings blood from the pelvic fin, enters the lateral vein. Find these veins.[1]

Cut away enough of the pectoral girdle and ventral body wall to give free access to the interior of the pericardial cavity; note the sinus venosus as it stretches across the hinder end of the cavity, to the dorsal wall of which it is attached. Slit open the sinus venosus, exposing its inner surface, and wash it out if necessary. Note its extension at each side in a dorsal direction to form the duct of Cuvier; probe this duct.

Cut across the main lobes of the liver and near the center of each find the large **hepatic sinus.** Follow each sinus forward, slitting it open; at its forward end find, by means of the probe, its opening into the sinus venosus. Note the small veins which are tributary to the hepatic sinus.

Find the posterior cardinal sinuses, then the lateral vein and the subclavian vein. The **posterior cardinals** extend along the entire length of the dorsal wall of the abdominal cavity. Their anterior ends communicate with each other; — they are a pair of very wide sacs just behind the false diaphragm and against the dorsal body wall. Posteriorly the sinuses are narrow, being long, slender vessels close to the median line and separated from each other only by the median vertical mesentery. Note the numerous small **renal veins** which enter them from the kidneys.

Slit open the right duct of Cuvier and wash it out if necessary; cut open the saclike anterior end of the posterior cardinal and trace it backwards.

Study the **anterior cardinal sinuses** which pass forward from the ends of the ducts of Cuvier. In order to find the anterior cardinal on the right side, turn the animal over so that its dorsal side is uppermost, and make a short, deep, longitudinal incision about halfway between the middorsal line and the foremost gill slits. The anterior cardinal sinus lies just above the gill arches and will be reached by the incision. Probe the sinus back to the duct of Cuvier and slit it open. Follow it forward

[1] These veins and sinuses can usually be studied without injection, because they are colored by the blood in them. If it is wished to inject them, it may be done through the lateral vein.

to the eye, where it opens into the orbital sinus which surrounds the eyeball.

Exercise 23. Draw a diagram of the systemic veins, so far as observed.

The arterial system. The principal vessels which form this system are the following: (1) the **ventral aorta,** or **aorta ascendens,** which passes forward from the conus arteriosus; (2) the **afferent branchial arteries,** which branch off from this aorta and carry venous blood to the gills; (3) the **efferent branchial arteries,** which collect the arterial blood from the gills and carry it dorsally to the middorsal line of the body cavity, where they form (4) the **dorsal aorta,** or **aorta descendens,** a median vessel which takes the blood to the hinder part of the abdominal cavity.[1]

Follow the **ventral aorta** from the conus arteriosus forward, cutting away the skin and muscles between the gill arches. Three **afferent arteries** will be seen to branch off on each side, the anterior and posterior ones of which divide each into two arteries. Follow these five arteries between the gill slits and study their relation to them.

Exercise 24. Make a semidiagrammatic drawing of the ventral aorta and the afferent arteries, showing their relation to the gill slits and arches.

We shall now study the **efferent branchial arteries,** the **dorsal aorta,** and their branches. Insert one blade of the scissors in the left corner of the mouth and carry an incision straight back across the gills as far as the pectoral girdle. From the end of this incision carry another across the floor of the pharynx to the opposite side of the body. Turn the flap thus formed, which is the entire ventral part of the head, over to the animal's right and pin it there, exposing the cavity of the mouth and pharynx.

[1] The ventral aorta and the afferent branchial arteries should be injected through the conus arteriosus. The rest of the arterial system may be injected through the caudal artery, which is the continuation in the tail of the dorsal aorta. Cut off the tail a short distance back of the anus and insert the canula in this artery.

Remove the mucous membrane from the roof of the mouth and pharynx and from the gill arches, being careful not to injure the blood vessels just beneath it. The cartilages forming the skull and gill arches will now come into view. Four prominent **efferent arteries** will be seen converging towards the median line, each one lying along the anterior border of a cartilage. Trace each artery forward to its gill slit and observe its two branches, one of which lies along each side of the slit, anastomosing at its lower end. The fifth gill slit, which has but a single gill, receives a branch of the fourth artery. Observe carefully the **short arteries** which connect the anterior branch of one efferent artery with the posterior branch of the one just in front of it.

Find and trace the branch of the fourth efferent artery which passes ventrally to the pericardial cavity and supplies it and the heart with blood; also the branches of the first efferent artery which go forward and supply the head.

The efferent arteries meet in the median plane and form the **dorsal aorta.** Issuing from the aorta between the third and fourth efferent arteries is a pair of **subclavian arteries.** One of these extends to the pectoral fin on each side and also gives rise to the **lateral artery,** which extends along the side of the body beneath the lateral line.

Exercise 25. Draw a diagrammatic sketch of the efferent branchial arteries and their branches.

The **dorsal aorta** is a large median artery which lies just beneath the spinal column in the body cavity; back of the anus it becomes the **caudal artery,** which lies in the ventral arches of the vertebral column. It gives off the following arteries: the **spinal arteries,** small paired vessels arising at regular intervals and going to the muscles of the body wall; the **cœliac artery,** a large median vessel which arises from the aorta near its anterior end and passes backward to the V-shaped portion of the stomach, where it sends branches to the stomach, liver, intestines, pancreas, and spleen; the **anterior mesenteric artery,** a median vessel which sends branches to the spleen and the spiral valve; the **posterior mesenteric artery,** which arises from the aorta near its

hinder end and passes to the rectal gland; the **renal arteries,** small paired arteries which leave the aorta at intervals along its course and go to the dorsal surface of the kidneys; the **iliac arteries,** a pair of small paired arteries which go to the pelvic fins.

Exercise 26. Draw a diagrammatic sketch of the dorsal aorta and its branches.

Exercise 27. Draw a diagram of the entire vascular system.

The body muscles. Remove the skin from a part of the body in the caudal region and study the muscles which form the sides of the body. On each side a series of muscle segments is present called **myotomes** or **myomeres,** which are separated from one another by connective-tissue septa called **myocommas.** Each myotome forms an irregular plate and is composed of parallel muscle fibers which will be seen running across from one myocomma to the other. The fibers are thus not bound together by fasciæ into distinct muscles, as is the case in the higher vertebrates. Note the zigzag shape of the outer edge of the myotome between the dorsal and the ventral sides of the body.

Exercise 28. Make an outline drawing of the side of the body, showing a few of the myotomes with their fibers, and the myocommas.

Cut the tail off a short distance behind the anus and examine the cut surface. The myotomes appear here in groups of concentric circles. This appearance is partly due to the zigzag shape of the myotomes. Cut horizontal and dorsoventral sections of the muscles and determine the exact shape and arrangement of the myotomes.

Observe the other structures in the cross section. In the center of it is the **spinal column.** The **neural arch,** within which is the spinal cord, forms its dorsal portion, and the **hæmal arch,** containing the caudal artery and the caudal vein, form its ventral portion; the vein is beneath the artery.

Exercise 29. Draw the cross section and label all of these features.

The skeletal system. The skeleton of the dogfish is made up of two distinct parts, the **exoskeleton** and the **endoskeleton.** The former is of integumental origin and consists of the placoid scales, the teeth, and the delicate horny rods in the fins. Each placoid scale consists of a basal plate of bone, which is sunk in the dermis of the skin, and a flattened toothlike spine, which projects backward through the epidermis. The basal plates are set close together so that the entire body of the animal, including the fins, is covered with a coat of mail of bone. The scales pass over the lips into the mouth and are continuous with the teeth, which have essentially the same structure as the spines of placoid scales.

Placoid scales have furnished the beginnings not only of teeth throughout the group of vertebrates but also of certain of the bones of the skull. Dogfish and their allies have no bony skull, but in the higher fishes and the higher vertebrates generally those bones called membrane bones, whose place in the skull was not taken by cartilage before the skull became a bony structure, but by membranes or portions of the integument, came into existence in the first place by the fusion of the bony plates of placoid scales.

Boil a piece of the skin in caustic potash and isolate the scales. Mount some of them in water and study them under the microscope.

Exercise 30. Make a drawing of several scales.

Exercise 31. Isolate several teeth and make a drawing of them.

The **endoskeleton** of the dogfish is the inner framework of the body. It is composed entirely of cartilage, which in certain places, as the vertebræ, is hardened by the presence of carbonate of lime. The race of sharks is an extremely ancient one, having been already in existence at the time in the world's history when cartilage and not bone was the principal constituent of the vertebrate skeleton. It has remained in this primitive condition down to the present time, although in all the higher fishes and in other vertebrates cartilage has given place to bone as the principal substance of which the skeleton is formed.

Notwithstanding this fact the sharks are at the present time, and probably have never ceased to be, the largest and most powerful fishes in the sea.

The endoskeleton may be divided into the **axial skeleton**, which consists of the skull including the gill arches, and the vertebral column and ribs, and the **appendicular skeleton**, which consists of the framework of the fins.

To prepare the endoskeleton for study, take an animal which has not been dissected, open the body cavity without cutting the pectoral or the pelvic girdle, and remove the viscera. Immerse the animal for a short time in hot water in order to soften the tissues, and then thoroughly remove the muscles from the cartilages. A stiff brush is useful in doing this, but great care must be exercised not to injure the more delicate cartilages of the gill arches and head. The skeleton must not be allowed to get dry but must be kept in water or formalin.

The axial skeleton. The **vertebral column** consists of a succession of vertebræ closely joined together by ligaments; they are also connected by the notochord, — a soft pulpy mass which runs through the axis of the vertebral column, filling the spaces between the vertebræ.

Each vertebra is made up of a cylindrical, deeply biconcave body called the **centrum**, to which are attached dorsal and either lateral or ventral projections. The concavities at the ends of the centrum are joined by a central canal, and this hourglass-like space is filled with the notochord. The inner surface of the centrum is calcified.

The dorsal projections of the centra form the **neural arches**; they inclose the neural canal, within which lies the spinal cord. Each arch consists of a pair of **neural processes**, which form its sides, and two small median **neural spines**, which form its roof. Between the neural processes are the **intercalary processes**, which are similar to them in shape and size.

The lateral and ventral projections of the centrum are respectively the **transverse processes** and the **hæmal processes**, which are the equivalents of each other. In the region of the trunk each centrum bears a pair of transverse processes; these are lateral

or latero-ventral projections, at the distal end of each of which is a short rib. In the caudal region, however, the ribs are absent and the processes project ventrally and meet in the median plane, forming the hæmal arches. Within these arches lie the caudal artery and vein.

Exercise 32. Draw the following views: (*a*) a side view of several consecutive vertebræ; (*b*) an end view of a trunk vertebra with the ribs belonging to it; (*c*) an end view of a caudal vertebra.

Exercise 33. Split a portion of the spinal column by a sagittal incision and draw the surface exposed.

The **skull** is made up of two very distinct portions,—the **cranium**, within which is the brain, and the sides of which are formed by the capsules containing the special sense organs, and the **visceral skeleton**, which incloses the anterior end of the alimentary canal and forms the gill arches and the skeleton of the mouth. Separate the cranium from the visceral skeleton and thoroughly clean the former.

The **cranium** is an irregularly shaped case of cartilage. The **orbit** which contains the eye and its muscles and nerves is a long, deep depression occupying the larger part of the side of it; behind this is the **auditory capsule**, which forms the hinder end of the skull; in front of it is the **nasal capsule**. The **rostrum**, the framework of the snout, forms the anterior end of the skull. In Mustelus the rostrum is formed of three delicate rods of cartilage which meet at their forward end; in Squalus the spaces between the rods are closed by thin plates of cartilage. Just behind the nasal capsule on each side is a large foramen through which the ophthalmic branches of the trigeminal and facial nerves emerge from the orbit. At the hinder end of the skull is the **foramen magnum**, a large aperture through which the spinal cord enters the brain cavity. In the dorsal surface of the hinder part of the skull is a deep depression, at the bottom of which are two small holes; these are the openings of the endolymphatic ducts. In the dorsal surface of the forward part of the skull is the

anterior fontanelle, a large opening into the brain-cavity which is closed by a fibrous membrane.

Exercise 34. Draw the dorsal view.

Study the lateral aspect of the skull. Note the great extent of the orbit and identify the following foramina in it: the **optic foramen,** a large hole for the passage of the optic nerve, which lies near the middle of the lower margin of the orbit; the **trochlear foramen,** a small hole above the optic foramen; the **anterior ophthalmic foramen,** near the anterior end of the orbit and dorsally situated, for the exit from the orbit of the ophthalmic branches of the trigeminal and facial nerves; the large **trigeminal foramen,** at the hinder end of the orbit, near its lower margin, for the passage of the trigeminal, the abducens, and a part of the facial nerves; the large **facial foramen,** above the trigeminal foramen, for the passage of the main portion of the facial nerve; the small **oculomotor foramen,** directly in front of the trigeminal foramen. Besides these foramina several other small ones are present which are occupied by blood vessels.

Posterior to the orbit is a shallow, longitudinal groove in which the anterior cardinal vein lies; the **glossopharyngeal foramen** is in it.

The ventral surface of the cranium is broad and flat posteriorly, and narrow between the orbits. It is crossed near the middle by two grooves in which arteries lie. At its anterior end are the openings of the nasal capsules.

Exercise 35. Draw a side view of the cranium and carefully label all these features.

Exercise 36. Draw a ventral view of the cranium.

Observe the foramen magnum. On either side of it are the two condyles by which the skull articulates with the trunk. At the side of each condyle is the **foramen** of the **vagus.**

The visceral skeleton. This consists of a series of seven arches beneath the cranium and the anterior end of the vertebral column which surround the pharynx and the mouth. Each arch is a paired structure consisting of a right and a left side which

meet in the midventral plane; each side is also made up of a dorsal and a ventral half.

The visceral arches fall into two groups, — an **anterior group** consisting of two arches, the first or **mandibular arch** and the second or **hyoid arch**, and a **posterior group** consisting of the posterior five arches, all of which support gills and are called the **branchial or gill arches**. A further distinction between these two groups is that the arches constituting the first alone appear as a portion of the head proper, those constituting the second group having migrated backward into the trunk. This condition is a secondary one and has been brought about by the shortening of the dorsal or cranial portion of the hinder part of the skull without a corresponding shortening of the ventral or visceral portion. The primitive position of all the visceral arches is on the head.

The **mandibular arch** forms the jaws of the animal. The dorsal half, or upper jaw, is formed of a pair of cartilages called the **pterygoquadrate cartilages**; the ventral half, or lower jaw, is formed of a pair called **Meckel's cartilages**. Each pterygoquadrate cartilage is joined with the base of the cranium by a strong ligament near its middle, and at its hinder end articulates with the lower jaw. The two halves of the lower jaw are joined together by a median ligament. The jaws are also joined with the second or hyoid arch by means of a ligament, and also with the base of the cranium. Slender, accessory **labial cartilages** are present in the lips at the side of both the upper and the lower jaw, two pairs being in the former and one in the latter.

The **hyoid arch** forms the principal support, or **suspensorium**, of the jaws; it also supports the tongue and bears the foremost pair of gills. Its dorsal half on each side is called the **hyomandibular cartilage**; it projects outward from the cranium, with which it articulates, and at its outer end is joined by short ligaments with the jaws and also by a long ligament with the base of the cranium. Projecting from its hinder border are several delicate cartilaginous rods called the **gill rays**, which support the gill filaments.

The ventral half of the hyoid arch on each side is called the **ceratohyal cartilage**; it bears gill rays on its hinder border. Joining

the two ceratohyals ventrally and projecting forward is the **basihyal cartilage**, which supports the tongue.

The five **branchial arches** are essentially alike in structure. Each arch is divided into four segments on each side, two dorsal and two ventral. The dorsal elements are the **pharyngobranchial** and the **epibranchial cartilages.** The former run obliquely backward, terminating dorsally beneath the spinal column, the posterior two pharyngobranchials being fused together; the latter are vertical in position and correspond to the hyomandibular cartilage. The ventral elements are the **ceratobranchial** and the **hypobranchial cartilages**, the former of which articulate with the epibranchials in the midlateral plane and the latter run obliquely backward to meet their fellows of the opposite side in the midventral line. The hypobranchials are not all alike. In Mustelus the posterior two pairs and in Squalus the posterior three pairs are fused together and with the fifth ceratobranchials, forming a broad median plate called the **basibranchial cartilage.**

The epibranchials and ceratobranchials of the first, second, third, and fourth branchial arches bear gill rays.

Along the outer sides of the second, third, and fourth branchial arches are three pairs of supernumerary cartilages called the **extrabranchials.**

Exercise 37. Draw a semidiagrammatic side view of the visceral skeleton.

Exercise 38. Draw a similar ventral view.

The appendicular skeleton; the median fins. The median fins are an anterior dorsal and a posterior dorsal fin, a ventral fin (in Mustelus but not in Squalus), and a caudal fin. The skeleton of the dorsal fins consists of a row of cartilaginous fin rays, the bases of which are often fused together, while at the outer ends are a number of small plates of cartilage. On each side of these fin rays, and extending beyond them, is a series of slender, horny fibers which develop in the skin and belong to the exoskeleton. The other median fins possess these fibers alone, the cartilaginous elements being much reduced or entirely absent.

The paired fins. These consist of the pectoral fins and the pelvic fins, which are supported by the pectoral and pelvic girdles respectively.

The **pelvic girdle** is an elongated plate of cartilage which extends transversely across the body in front of the anus and articulates with the pelvic fins. The skeleton of the **pelvic fin** consists of a long, more or less curved rod of cartilage called the **basipterygium,** which extends straight back from the girdle. The cartilaginous **fin rays** articulate with this and the girdle; the distal portion of the fin is supported by dermal horny rays.

In the male the basipterygium is much extended by the addition of a second long cartilaginous rod at its posterior end, which is grooved on its upper surface and forms the **clasper.**

Exercise 39. Draw the pelvic fin and girdle.

The **pectoral girdle** is a U-shaped cartilaginous arch which lies transversely across the ventral and on the lateral sides of the body, immediately back of the gill arches. On each side of the ventral portion of the girdle is a depression, the **glenoid fossa,** in which the fin articulates, and which divides the girdle into a dorsal or **scapular** and a ventral or **coracoid portion.**

The pectoral fin articulates with the pectoral girdle by three basal cartilages, the **propterygium,** the **mesopterygium,** and the **metapterygium,** of which the last named is the hindermost. Along the outer margin of these cartilages is a series of cartilaginous **fin rays,** many of which are segmented; these fin rays do not, however, support the entire fin, but only its basal portion, the distal half being supported by dermal horny rays.

Exercise 40. Draw the pectoral girdle and fin showing exactly the outlines of all the cartilages.

A TELEOSTEAN FISH. THE PERCH

The perch is one of the commonest fresh-water fishes. It is found almost everywhere in streams, ponds, and lakes, where it lives on small aquatic animals of every kind. Any other bony fish may be used in place of the perch; the differences in structure which exist will not confuse the dissection. Two or three specimens will be needed for each student; during the progress of the dissection they should be kept in a five per cent solution of formalin.

Observe the form and external markings of the animal. The body of the perch, like that of the majority of teleosts, is elongated and laterally compressed, with a wedge-shaped head and a terminal mouth; the hinder end is less compressed than the forward portion and terminates with a homocercal fin, which is the principal organ of locomotion. The other fins are all of good size and may be used both for purposes of locomotion and as a means of defense against attack, the sharp spines with which most of them are provided being formidable weapons.

The entire body, with the exception of a part of the head and the fins, is covered with **ctenoid scales**, which are not placed side by side, as are the placoid scales of the dogfish, but overlap one another posteriorly. Examine them carefully on different parts of the body and note their arrangement and difference in size. If the fish is fresh, note the slimy, transparent epidermis which covers the scales; if it is not fresh, scrape off some of the dried epidermis. Note the **lateral line** which runs along each side of the body parallel with the back its entire length; it is an organ of special sense.

Observe the color bands and their arrangement. Are they bilaterally symmetrical? Note that the color consists of an aggregation of small dots, except where it forms solid masses. These dots are pigment cells; they are just beneath the epidermis in the outer layer of the dermis and may be scraped off

with the epidermis. Note the structure of a single dot; it will be seen to consist of a black central kernel, — the body of the cell, — surrounded by a halo of fine dots which constitute its outlying projections. Many fishes have the power of changing their color in a remarkable degree, although it is probably a reflex action in them and not under the control of the will. It is accomplished by the often very rapid variation in the extent of these pigment cells, which in such cases are amœboid.

The body may be divided into three regions, the **head, trunk,** and **tail,** — the boundary between the latter two regions being the anus. There is no neck.

Vertebrates which live in the water differ much from those living on the land in the arrangement of the body regions. Water animals must force their way through a dense medium, and hence the forward portion of the body is rigid and usually more or less wedge-shaped. A neck region is thus absent, it being essentially a flexible one. Even in those mammals which have adapted themselves to a wholly aquatic life, as the cetaceans, the neck region is so much reduced that the head and trunk are in direct contact with each other. In every animal which moves rapidly, however, at least one flexible body region must be present where the body can turn when the direction of movement is to be changed. In the fish this is accomplished in the caudal region; in most mammals it is in the lumbar region.

The head. The head of teleostean fishes differs from that of land vertebrates in that it contains the organs of respiration and the heart. The head is flattened ventrally and dorsally, with the large **mouth** at its anterior and the **gills** at its posterior end. The opening of the mouth is bounded ventrally by the paired **mandibles,** and dorsally by the paired **premaxillæ,** above which on each side is the flattened **maxilla.** The large **eyes** are without lids. A transparent membrane called the **conjunctiva** passes over the front of the eye and is continuous with the epidermal layer of the skin; a deep fold of the skin is also present around the eye, joining it with the skin of the head, and yet permitting it considerable freedom of motion in its socket.

In front of the eyes are two pairs of **nostrils**; there is, however, but a single pair of nasal capsules, each capsule having two external openings. Note the difference in shape of these two nostrils and the valve which overhangs the anterior one. The nasal capsules do not open posteriorly into the mouth, but are wholly sensory in function.

At the posterior end of the head is the large **operculum**, or gill cover, and at its hinder margin, the **gill openings**. Note the sharp protective spine which projects back from each operculum. Along the hinder and lower border of the operculum is the **branchiostegal membrane**, supported by seven parallel bony rays, the **branchiostegal rays**, which forms a valve guarding the gill opening. Underneath the operculum on each side will be seen the four **gill arches**, which bear the red **gills**, and the clefts between the arches. Note the rudimentary gill, the **pseudobranch**, which appears as a red patch on the inner surface of the operculum in front of the first gill arch.

Cut off the left operculum and probe between the gill clefts into the pharynx. Observe carefully the form and position of the gill arches and the double row of **gill filaments** on each; also the **gill rakers**,—the row of spiny projections on the side of each arch, which prevent food from passing through the clefts. In the elasmobranch the gill clefts are not covered by an operculum.

The trunk and caudal region. These two regions pass gradually into each other; they bear the **appendages**. At the posterior end of the trunk are the **anus** and the **genital** and **urinary pores**. The anus is the largest and most anterior of these three openings; the other two are minute and are situated behind it on a small papilla. Behind this is often a transverse depression.

The appendages. Two kinds of appendages are present,—the **paired fins** and the **median fins**. The latter are the more primitive structures and are alone present in the lowest fishes; they are simply dorsal and ventral flattened expansions of the body, which are stiffened by bony rays. In the perch two **dorsal fins** and one **ventral** or **anal fin** are present, and one homocercal **caudal fin**. Note carefully which of these fins have sharp spiny rays,

and in which the ends of the rays are divided and flexible. Observe that the two dorsal fins are nearly continuous with each other.

The paired fins are also expansions of the body wall, stiffened by bony rays; they are homologous to the appendages of the higher vertebrates. Two pairs are present,—an anterior pair, the **pectoral fins**; and a posterior pair, the **pelvic fins**. The former are nearly vertical in position and are situated on the side of the trunk just behind the operculum. They are supported by a bony arch within the body wall just back of the gills, which is called the **pectoral girdle**. The pelvic fins are a short distance behind them and are nearly horizontal in position. In the more primitive fishes the pelvic fins are situated just in front of the anus. Note that in all the fins the rays with split tips are segmented.

Exercise 1. Draw a view of the right side of the animal; do not draw the scales. Label the organs carefully.

Exercise 2. Draw the ventral view.

The internal organs. It will be well first to cut off the sharp tips of the dorsal fins to keep them from hurting the hands. The internal organs will be exposed by removing the left side of the body wall. After placing a probe in the anus to mark it, make a straight incision through the body wall from just in front of the anus to the mouth, cutting through the midventral point of the lower jaw. Care must be taken not to cut the organs which lie in the body cavity. Make then a deep cut downward and inward along the lateral line on the left side of the body until the scalpel strikes the spinal column or the basal portion of the ribs; cut always against the outer edges of the scales, from behind forward. When the scalpel will go no farther pass it ventrally along the outer surface of the ribs and remove the muscles of the side of the body.

Determine now definitely the position of the spinal column, since it marks the dorsal boundary of the abdominal cavity, and carefully cut away the entire left body wall, removing thus the ribs with any muscles which may still be attached to them, the

left pectoral fin and pectoral girdle, and the left pelvic fin. It is best in doing this to work from the midventral incision upward, as in this way the internal organs are brought gradually into view as the work proceeds. The liver, intestine, and reproductive organs, which are sometimes very large, will first be seen; then, dorsal to them, the air bladder. This organ adheres closely to the body wall and special care must be taken not to injure it; its ventral wall forms a wall across the body cavity which is tough and strong, its lateral walls becoming thinner dorsally.

Having removed the left body wall, cut away with scissors the portion of the right body wall between the midventral incision and the air bladder.

Place the animal in a pan of water and examine the organs, without, however, disturbing them. Note the glistening **peritoneum**,—the membrane which lines the abdominal cavity; it passes along the ventral side of the air bladder. The **mesenteries**, the membranes which support the intestine and the other organs in the abdominal cavity, are folds of the peritoneum.

The **body cavity** is made up of two divisions, the larger and posterior of which is the **abdominal cavity**, the anterior and very much smaller one being the **pericardial cavity**. The former is lined by the **peritoneum** and contains most of the viscera; the latter is lined by the **pericardium** and contains the heart. These two cavities are separated from each other by the **false diaphragm**, which is composed of the posterior wall of the pericardium and the anterior wall of the peritoneum; it is not homologous to the diaphragm of mammals.

In the abdominal cavity the largest organ is the **air bladder**, which extends the entire length of the cavity and occupies the dorsal half of its space. In the perch it is a simple sac which is not connected with the pharynx by a duct, as is the case in the trout, catfish, and many other fishes. On the inner surface of its ventral wall a pair of red patches composed of a network of capillaries will be noticed. The air bladder is a hydrostatical apparatus by means of which the fish can maintain its position in the water at different depths without conscious effort.

At the anterior end of the abdominal cavity and just back of the false diaphragm is the large red **liver**; at the posterior end, running back to the anus, is the **intestine**, which is usually inclosed in fat. The anterior portion of the intestine forms a coil lying a little to the right of the median plane, within which, often imbedded in fat, lies the **spleen.** On the animal's left, more or less covered by the hinder border of the liver, is the **stomach**, a large cylindrical body; alongside of it are several elongated **pyloric appendages.**

The **gonads**, or **genital glands**, which consist of the paired testes in the male and the single ovary in the female, vary much in size at different seasons of the year. They are often very large and may occupy a large portion of the abdominal cavity. They will be seen just dorsal to the intestine, extending from the hinder end of the cavity forward.

In the pericardial cavity, beneath (dorsal to) the thick muscles between the gills, will be seen the **heart.** It consists of the median **ventricle**, a large muscular organ, at the sides of which appears the deep red **auricle**; at the back of (dorsal to) this organ is the **sinus venosus**, a large, deep red sac which communicates with the auricle. In front of the ventricle is the large **bulbus arteriosus** which is the beginning of the aorta.

Exercise 3. Make a semidiagrammatic sketch of the left side of the fish, showing the opened body cavity and its organs as they appear before they have been disturbed; label them all carefully.

The digestive system. This consists of the mouth, pharynx, œsophagus, stomach with the pyloric appendages, intestine, and liver; a pancreas may also be present.

The mouth and pharynx. Cut away the left half of the lower jaw and the gill arches, but do not injure the heart; the mouth and pharynx are thus fully exposed. They will be seen to form a single large space extending from the opening of the mouth to the œsophagus, the pharynx being the portion of the space which contains the gills.

The teeth are very small and are present not only in the upper and lower jaws but also on the roof of the mouth and the roof and floor of the pharynx. Examine them carefully with the aid of a hand lens. There are three groups of teeth on the roof of the mouth, a small median patch of **vomerine teeth**, and a pair of lateral patches of **maxillary teeth.** Note carefully the position of the teeth on the gill arches.

Just within the margin of each jaw is a transverse membrane; probe behind them. These two membranes are the **oral valves**, which prevent the water from flowing out again through the mouth during respiration. Breathing consists of two actions,— the inspiration and the expiration. At the inspiration the oral valves open and the branchiostegal membranes, which form valves at the opening of the operculum on each side, close; at the expiration the oral valves close and the branchiostegal valves open, allowing the respiratory water to pass out through the gill clefts.

Observe carefully the form and arrangement of the **gill arches.** Note the **gill rakers**,—the short spiny projections on the gill arches which prevent solid substances from passing out through the gill clefts. Cut out a gill arch and examine the **gills** on it. Observe that a double row of **gill filaments** is present. Study carefully the arrangement of these filaments with reference to the gill arch and with reference to each other. In fishes the gills are outgrowths of the wall of the pharynx. In the ventral wall of the mouth is the **tongue**; note its relation to the gill arches.

Exercise 4. Draw a sketch of the mouth and pharynx, showing both dorsal and ventral surfaces with the features above described.

Exercise 5. Draw a diagram of a gill arch with its two rows of gill filaments.

Study the remainder of the digestive tract. Observe the short, wide **œsophagus**, which joins the pharynx with the stomach. Turn the left lobe of the liver to one side and observe

the anterior or **cardiac end** of the stomach. Note the shape of the **liver** and the mesentery which attaches it to the anterior abdominal wall; cut this mesentery. Note the mesentery which joins the stomach with the ventral wall of the air bladder, and cut it. Note that a part of the intestine lies free and is not attached to the body wall by a mesentery. Cut the œsophagus and remove the entire digestive tract from the body, retaining, however, its posterior attachment at the anus.

Study its various parts. The stomach has three distinct regions, — an **anterior region**, which extends straight back from its cardiac portion and ends posteriorly in a blind sac; a **posterior region**, which leaves the anterior region at right angles near its middle and extends to the beginning of the intestine; and the **pyloric appendages**, three long, cylindrical blind sacs. Just back of these appendages is a slight constriction which marks the **pyloric** or hinder end of the stomach.

The **intestine** begins at the pylorus and extends to the anus. It is composed of three divisions: the **duodenum** (which includes the anterior loop of the intestine, between the limbs of which the spleen lies), the **small intestine**, and the **rectum**, — the boundary between the last two divisions being the circular ridge about an inch in front of the anus. The **liver** is a large gland which communicates with the intestine by means of the **bile duct**. This duct emerges from the **gall bladder**, which lies against the posterior surface of the liver, receives a number of branch ducts from the liver, and joins the intestine near the base of the pyloric appendages. A pancreas has not been found.

Exercise 6. Draw a semidiagrammatic sketch of the digestive tract and label carefully all of its parts.

Slit open the stomach and a portion of the intestine and examine their inner surface.

The urogenital system; the male genital organs. The **testes** are a pair of white, elongated bodies which lie in the abdominal cavity just ventral to the air bladder, to which they are joined by a mesentery. They taper towards the hinder end and finally fuse together, the median portion thus formed passing directly

to the genital pore just behind the anus. The actual size of the testes depends upon the sexual condition of the animal; during the breeding season they are large and may extend into the anterior portion of the abdominal cavity.

The female genital organs. The **ovary** is a median body which lies in the abdominal cavity between the intestine and the air bladder, and is joined to the latter by a mesentery. It is an elongated sac filled with small ova and varies in size with the sexual condition of the animal; no oviduct is present, the hinder part of the ovary becoming gradually smaller and finally communicating with the outside through the genital pore just back of the anus.

Exercise 7. Make a sketch of the genital organs.

The urinary organs. Remove the testes or the ovary. Dissect the air bladder away from the body wall and remove it. Note the thinness of its dorsal wall, where it lies just beneath the **kidneys.** These organs are a pair of slender deep red bands which lie close against the dorsal body wall, one on each side of the vertebral column. Their anterior ends unite just dorsal to the œsophagus and form a large, dark-colored median mass called the **head kidney**, which extends across the body cavity. Dissect away the remains of the œsophagus and note the exact shape and extent of the head kidney. The **ureters** are a pair of tubes which run along the entire length of the medial borders of the kidneys, joining at their hinder ends. The single vessel thus formed then passes to the minute **urinary pore** just back of the genital pore; a small **urinary bladder** projects from the median portion of the ureters.

Exercise 8. Draw a sketch of the urinary system within an outline of the body and the body cavity.

The **nervous system** consists of (1) the **central nervous system,** which includes the brain and the spinal cord; (2) the **peripheral nervous system,** which includes the paired cranial and spinal nerves and the sympathetic nervous system; and (3) the **special sense organs.**

We shall study first the **special sense organs**; they are the integumentary sense organs, the nasal organs, the eyes, and the ears.

The **integumentary sense organs** consist of (*a*) minute scattered **sense buds** which occur principally on the head but also on the body, and (*b*) of the **lateral line.** This line is a straight canal in the integument which extends along the side of the body from the head to the caudal fin, with branches also upon the head, in which are groups of sensory cells. At regular intervals are minute openings to the outside through the scales; each scale covering the lateral line has a canal on its inner side which is a branch of the main canal and communicates with the outside through a pore at its hinder end.

The **nasal capsules** are a pair of sacs situated in front of the eyes and communicating with the outside by two nostrils on each side; no communication with the mouth is present. Cut off the outer wall of one of the capsules and observe the delicate folds of the sensory epithelium radiating from a central point.

Exercise 9. Make a drawing of the capsule on a large scale.

Cut away the folds of the capsule and observe the olfactory nerve which enters it at its hinder side.

The eyes. Observe the central **pupil** of the eye through which light is admitted to the interior of it, the **iris** which surrounds the pupil, and the transparent **cornea** which lies in front of both and forms the outer coating of the eye. Observe carefully the circular fold of the skin which surrounds the front of the eyeball.

With strong scissors cut away the circular ridge of the skull which surrounds the eye, and remove the muscles of the head just beneath and back of it. Remove also the slimy fold of the skin just mentioned, which surrounds the front of the eye. Note that a transparent layer of the skin passes over the cornea and may be peeled off; this is the **conjunctiva.**

Observe the position of the eye in the orbit; it is held in place by the optic nerve, which joins it at its inner end, and by six small muscles. These muscles have their origin in the wall of the orbit, and their insertion in the outer coating of the eyeball, the movements of which they control.

Study these **muscles**. Press the eyeball downward and note on its medial side the insertions of two muscles; the anterior one is the **superior oblique**, which goes from the eyeball to the inner, anterior wall of the orbit; the posterior one is the **superior rectus**, which goes from the eyeball to the inner, posterior wall of the orbit. Push the eyeball backward and note the **inferior oblique muscle**, which has its insertion on its antero-ventral surface and passes parallel with the superior oblique to the inner, anterior wall of the orbit. On the posterior side of the eyeball is the insertion of the **external rectus muscle**, which runs to the inner, posterior wall of the orbit. Cut the superior oblique muscle at its insertion in the eyeball; beneath it will be seen the insertion of the **internal rectus**, which runs back to the inner, posterior wall of the orbit. Cut all these muscles at their insertion in the eyeball and pull it gently outward and forward; the **inferior rectus** will be seen, whose insertion is on the inner side of the eyeball and which runs to the inner posterior wall of the orbit. Cut this muscle and the optic nerve and remove the eyeball from the orbit. Note the origins of the four rectus muscles in the posterior wall of the orbit, and of the two oblique muscles in the forward wall of the orbit.

Exercise 10. Draw a sketch of the orbit, showing its muscles and the optic nerve.

Study the eyeball. Its tough outer covering is the **sclerotic coat**, or the **sclera**, of which the cornea is the portion in front. Cut it in two lateral halves; remove the other eye and cut it in an anterior and a posterior half; study the interior of both under water. Just back of the pupil is the spherical **crystalline lens**; do not remove it. This is the shape of the lens in all vertebrates which live under water. In a dense medium like water vision is necessarily limited in range, and fishes can only see objects which are close to them. An eye with a spherical lens is shortsighted.

The inner coating of the eye is the **retina**. Between it and the sclerotic coat is the **choroid coat**. This consists of three layers, — the black **pigment layer** which lies just beneath the retina, the

glistening **silvery layer** which is just within the sclera, and the **vascular layer** which contains blood vessels. Around the entrance of the optic nerve the vascular layer is much thickened. The portion of the choroid which extends over the front of the eye is the **iris**, the central opening of which is the pupil; delicate muscles in the iris control the size of the pupil. Around the inner side of the iris a ridge called the **ciliary process** extends to the lens, and is continuous with the delicate membrane in which the lens is suspended.

Note the **blind spot**, the point where the optic nerve enters the eye. From near this spot a slender projection of the choroid, called the **falciform process**, which ends in an enlargement called the **campanula Halleri**, extends through the retina to the side of the lens, to which it is attached. The campanula contains smooth muscle fibers by the action of which the position of the lens is slightly changed and its focus altered. The range of accommodation is, however, very small. Use the hand lens in studying the falciform process; it is usually easily found.

The two large chambers of the eye are the one between the iris and the cornea, which is filled with the watery **aqueous humor**, and that between the retina and the lens, which is filled with the jellylike **vitreous humor**.

Exercise 11. Draw a diagram representing the structure of the eye.

The ear. The auditory organ consists of the membranous labyrinth alone, which is imbedded in the cranium back of the eye; no external opening exists. To dissect it out is a difficult task, but with care and patience it can be done. The auditory capsule, which contains the membranous labyrinth, is an extensive cavity in the cranium, which is in communication with the brain cavity; it also contains the peculiar granular, fatty matter which fills the brain cavity. The labyrinth is imbedded partly in this fatty matter and partly in cartilage. It is made up of the saclike vestibule, three semicircular canals, and an endolymphatic duct.

Carefully shave away the bony wall of the skull just back of the orbit, and look first for the **semicircular canals.** Two of these are vertical in position and rise to the dorsal wall of the skull, the anterior and larger of the two being imbedded in the granular, fatty matter, and the posterior one being inclosed in cartilage. Having found these canals and dissected them free, look for the third semicircular canal, which has a horizontal position. Note that one end of each canal is swollen; this is the **ampulla.**

The semicircular canals project from the **vestibule.** This is a saccular structure which is composed of two parts, the **utriculus** and the **sacculus,** the latter being ventral to the former, and being nearly filled by a single very large **otolith,** — a flattened, very hard, bony structure, with prominent serrations at its hinder end. At the anterior end of the sacculus is a small pocket containing a minute otolith called the **lagena**; this is the structure which in mammals becomes the cochlea. The **endolymphatic duct** is a very slender, straight tube, which passes dorsally from the sacculus and ends blind. It is the remains of the embryonic invagination which during the development of the animal resulted in the formation of the membranous labyrinth.

Another method of dissecting the ear is to split the skull and brain by an incision in the sagittal plane, to remove the brain, and then carefully scrape away the fatty matter at the intersection of the auditory and the brain cavities until the membranous labyrinth is exposed.

The ear in most fishes is not an organ of hearing but of equilibration, its function being to enable the animal to maintain the proper position in the water.

Exercise 12. Draw the membranous labyrinth, so far as observed.

The brain. If the brain has been kept in strong formalin, as directed, it will have been hardened and will be in good condition for dissection; if, however, its condition is for any reason no longer suitable, a fresh animal must be taken.

Remove all the skin and the thick muscles from the head and the high-arched dorsal portion of the trunk just back of it. With a strong scalpel or scissors cut away the roof of the skull and the dorsal wall of the neural canal of the spinal column. The brain does not nearly fill the cavity of the skull but is surrounded by the granular, fatty tissue already mentioned; carefully remove this substance and expose the brain.

Study its dorsal surface. It is made up of five divisions. The first and anterior division is the **cerebrum**; it consists of a pair of **hemispheres**, at the anterior ends of which project the **olfactory lobes**. The third division, or **midbrain**, consists of the paired **optic lobes**, the largest part of the brain, between which and the cerebrum appears a small, median, sunken area, — the **thalamencephalon**, the second division. Projecting dorsally from this division is the long and slender **pineal body**, or **epiphysis**, which is the rudiment of a third optic nerve; it may have been removed in exposing the brain. Back of the optic lobes are the fourth division, the **cerebellum**, and the fifth division, the **medulla oblongata**, which is continuous with the **spinal cord**. Note the longitudinal median groove in the medulla and spinal cord, and the paired lateral swellings, the **restiform bodies**, at the anterior end of the former.

Exercise 13. Draw a dorsal view of the brain on a scale of 3 or 4.

Carefully cut away one side of the skull and expose the side of the brain. Find the ten **cranial nerves**. The first nerve is the long **olfactory**, which passes forward from the olfactory lobe to the nasal capsule. The second is the **optic nerve**, which arises just in front of the optic lobe from the ventral surface of the thalamencephalon; the two optic nerves cross each other immediately, forming the **optic chiasma**, and pass each to the eye on the opposite side of the body. By carefully pressing the floor of the brain case away from the brain the root of the optic nerve will be seen; the nerve may then be traced to the optic foramen where it enters the orbit. The third cranial nerve, the **oculomotor**, is a small nerve which will be seen arising on the ventral surface of the brain beneath the optic lobe and passing forward to the

orbit, which it enters back of the optic foramen. The fourth nerve, the **trochlear**, is about the size of the third, and will be seen arising just back of the optic lobe on the side of the brain and passing forward to the orbit, which it enters above the optic foramen.

The fifth nerve, the **trigeminal**, and the seventh, the **facial**, arise together, although without any intermingling of their fibers, from the side of the anterior end of the medulla; this common root will be easily recognized by its large size. The two nerves leave the cranium together. The trigeminal then splits up into the following three nerves: (1) the **ophthalmic nerve**, which passes forward along the wall of the orbit, dorsal to the optic nerve, to the anterior surface of the head; (2) the **maxillary nerve**, which goes to the upper jaw; and (3) the **mandibular nerve**, which goes to the lower jaw. The **facial nerve** passes backward and, dividing into branches, supplies the lower jaw, the operculum, and the branchiostegal membrane.

The sixth nerves, the **abducens**, are a pair of very small nerves which arise near the midventral line of the brain and pass to the orbits; they may be seen when the ventral surface of the brain is studied. The eighth nerve, the **auditory**, arises on the side of the medulla just back of the common root of the trigeminal and facial nerves; it at once divides into three branches which go to the auditory capsule. The ninth nerve, the **glossopharyngeal**, and the tenth, the **vagus** or **pneumogastric**, arise together on the side of the medulla by three roots. The smallest of these roots is the glossopharyngeal nerve, which passes backward to the first gill arch. The two largest roots join and form the vagus nerve, which, passing posteriorly, supplies the gill arches, except the first, and the heart, stomach, and lateral line. Follow it and its branches as far as possible.

Exercise 14. Draw the side view of the brain and the cranial nerves so far as observed, on a scale of 3 or 4.

Cut the olfactory nerves; loosen the brain from its attachments, bend it back, and remove it from the body. Study its

ventral surface. At its anterior end will be seen the small **hemispheres** with the **olfactory lobes** at their anterior ends. Back of them is the **thalamencephalon**, from which project the following structures: (*a*) the **optic nerves** with the **optic chiasma**, and (*b*) the median **infundibulum**, at the lower end of which is the **hypophysis** or **pituitary body**, and at whose sides are a pair of large swellings called the **lobi inferiores**. At the side of each of these swellings on the ventral surface of the brain the **oculomotor nerve** arises, while posterior to them is the **medulla oblongata**. Note the **median furrow** in it and the roots of the delicate **abducens**, near the median line. Identify the roots of the other cranial nerves.

Exercise 15. Draw the ventral aspect of the brain on a scale of 3 or 4.

Cut the brain in two in exactly the sagittal plane and study the cut surface. The brain is a hollow structure; in it is a series of cavities which are a continuation of the central canal of the spinal cord. The most posterior of these cavities, which is directly continuous with the central canal, is in the medulla, and is called the **fourth ventricle**; the cerebellum projects partly over it. Note the thick ventral wall and the thin dorsal wall of this ventricle. Note also that the cerebellum is solid and that beneath it the fourth ventricle continues forward between the optic lobes, forming a canal called the **aqueductus Sylvii**; this canal goes to the thalamencephalon, where it is called the **third ventricle.**

The optic lobes are hollow, the cavity in them communicating with the aqueductus Sylvii. On the floor of each lobe is a crescent-shaped ridge called the **torus.** A W-shaped median fold of the posterior wall of the lobes will be seen between the two tori, and in front of it a median fold of the anterior wall. Carefully remove the thin dorsal wall of one of the lobes and study these structures.

In the two hemispheres are the **first** and **second**, or **lateral**, **ventricles**, which are shallow spaces communicating with the third ventricle. Make a transverse section of one of the hemispheres

and note the floor of its ventricle; this is much thickened and is called the **corpus striatum.**

Exercise 16. Draw the sagittal section on a scale of 3 or 4.

The vascular system. This is made up of the following organs: (1) the **heart,** which receives venous blood from the tissues and forwards it to the gills; (2) the **arteries,** which carry (*a*) venous blood from the heart to the gills, and (*b*) arterial blood from the gills to the tissues; (3) the **veins,** which carry venous blood to the heart; and (4) the **capillaries.**

The veins. Two distinct systems of veins are present, one of which is composed of the **systemic veins,** which carry blood directly to the heart; the other is composed of those which carry blood first to the liver, and is called the **portal system.**

We shall first study the latter system. Take a fresh animal and open its body cavity by a midventral incision. Cut away both the right and the left body walls between the incision and the air bladder. The **portal system** consists of a pair of **intestinal veins** which lie alongside the intestine, a **splenic vein** from the spleen, several **gastric veins** from the stomach, and a **pneumatocystic vein** from the air bladder, all of which unite to form the single large **portal vein.** This vein passes to the hinder surface of the liver, where it breaks into branches which carry the blood to all parts of that organ.

The veins of this system are often difficult to dissect because of the fat in which they usually lie imbedded. First find the two intestinal veins and free them from the fat. Lift up the spleen and the duodenal loop in which it lies and find the point of union of these two veins; find also the splenic vein, the gastric veins from the stomach proper and the pyloric appendages, and the pneumatocystic vein from the air bladder. Note the exact arrangement of these veins; also the branching of the portal vein on the hinder surface of the liver.

Exercise 17. Draw a semidiagrammatic view of the portal system.

The heart and the pericardial space. Cut away all the muscles between the gills, being very careful not to injure the heart or

the artery which issues from its forward end; the pericardial cavity will be thus exposed.

The **heart** in fishes stands in close relation to the gills, and lies in the postero-ventral portion of the head between them. It is made up, as we have seen, of three parts, the large muscular **ventricle**, the deep red **auricle**, and the **sinus venosus**, the vessel which lies across the hinder end of the pericardial space. Blood is brought from the various tissues to the sinus venosus by the veins, from which it flows into the auricle, and from it into the ventricle.

The ventricle sends the blood forward into the **bulbus arteriosus**, — a thick-walled vessel in front of the ventricle, which is the beginning of the aorta. The muscular walls of the bulbus are highly elastic, and when they are distended they exert a constant pressure upon the blood which is passing through it; the blood thus flows forward in a constant stream and without pulse beats.

Exercise 18. Draw a semidiagrammatic view of the pericardial cavity with the heart and the bulbus arteriosus.

The inner structure of the heart. Cut open the ventricle and the bulbus arteriosus by a lateral incision carried along the left side of both. Turn the flap, which consists of the entire ventral wall of the ventricle and bulbus, to the right, and expose their interior. Note the thick walls of the ventricle and the small cavity in the center; in its dorsal wall is the **auriculo-ventricular opening** into the auricle, — a slit guarded on each side by a valve. Use the blowpipe to bring this opening into view. Note also the thick walls of the bulbus; find by using the blowpipe, at the opening of the ventricle into the bulbus, the two valves which prevent the blood from flowing backward. Open the auricle by a lateral incision; blow into it and note its thin walls and large cavity. Find the opening into the sinus venosus, which is guarded by a single valve.

Exercise 19. Draw a diagram of the heart, showing the structure of its interior.

The arterial system.[1] The forward continuation of the bulbus arteriosus forms the **aorta ascendens,** or **ventral aorta.** This vessel sends off four pairs of **afferent branchial arteries** which carry blood to the gills: four pairs of **efferent branchial arteries** then run from the gill arches dorsally to the median plane where they form the **aorta descendens,** or **dorsal aorta.**

Springing from the dorsal end of the first (anterior) efferent branchial artery, on each side, is the large **carotid artery,** which supplies the head; it soon divides into two branches which pass above and below the eye. The dorsal aorta passes along the dorsal side of the body cavity, just beneath the spinal column, to the posterior end of the body; in the caudal region it becomes the **caudal artery** and lies in the ventral arches of the vertebræ. It gives off the paired **spinal arteries** along its entire course; the **cœliac artery,** a large median vessel which leaves the aorta a short distance back of the branchial arteries, and, breaking up into a number of branches, supplies the digestive tract, air bladder, and genital glands; and the two **subclavian arteries,** which leave the aorta just back of the cœliac artery and go to the pectoral fins.

First study the ventral aorta and the afferent branchial arteries. Entirely remove the lower jaw and the left operculum, but do not disturb the gill arches; with scissors cut off the gills from the arches. Follow the ventral aorta from the bulbus arteriosus forward between the ventral ends of the gill arches. Find the points where the four afferent arteries on the left side leave the aorta, and trace the course of each along the hinder side of the gill arches; the transparency of the skin covering the gill arches permits this to be done easily.

The remaining arteries will be studied after the veins.

Exercise 20. Draw the arteries just observed.

[1] The aorta ascendens and afferent branchial arteries may be injected through the bulbus arteriosus. In order to inject the remainder of the arterial system, cut off the tail a short distance in front of the caudal fin and inject forward in the caudal artery. This is the uppermost of the two vessels which lie in the canal formed by the bony arches on the ventral side of the spinal column.

The venous system (*continued*).[1] The following are the systemic veins, which carry blood directly to the heart. The short **hepatic vein** enters the sinus venosus in the median plane. Press the liver away from the false diaphragm and find it. Joining each end of the transverse sinus venosus is a large and conspicuous duct or sinus called the **Cuvierian duct.** The two Cuvierian ducts lie along the anterior end of the abdominal cavity, parallel with each other and just in front of the liver, between the sinus venosus and the head kidney. Inasmuch as the head kidney is dorsal in position and the sinus venosus ventral, the Cuvierian ducts have an almost vertical position in the body. Trace these vessels from the sinus venosus dorsally: they will be found just behind the posterior gill arch. The dorsal ends of these two ducts are connected by a horizontal sinus which lies just beneath the spinal column.

Two pairs of prominent veins — the **jugulars** or **anterior cardinals,** and the **posterior cardinals** — bring blood from the anterior and the posterior portions of the body, respectively, to the horizontal sinus of the Cuvierian ducts. Just before joining the sinus the two jugulars unite and form a median vein; the two posterior cardinals also unite and form a median vein.

The two posterior cardinals are large and prominent veins and lie just beneath the vertebral column, partly imbedded in the kidneys; the dorsal aorta lies between them. The **left cardinal** is much larger than the right, and much longer, and begins its course at the posterior end of the body as the **caudal vein**; this vein lies in the ventral arches of the spinal column and receives the paired **spinal veins.**

In the trunk region it receives the **left spinal** and **renal veins.** The **right cardinal** begins its course in the hinder part of the body cavity and receives the **right spinal** and **renal veins.** Find the cardinals in the mass of the kidneys and trace them forward to the median cardinal and the Cuvierian ducts.

[1] The veins are easily studied without injection, as the death of the animal leaves them filled with blood. If it is wished to inject them, however, this may be done through the caudal vein, which is the lowermost of the two vessels in the ventral canal of the vertebral column.

Find the median jugular vein and trace it and the two jugulars and their branches as far as possible.

Entering the horizontal sinus are three additional veins. Two of these are the small paired **subclavian veins**, which bring blood from the pectoral fins; the third is the **intestinal vein**, which brings blood from the stomach, intestine, and genital organs. Follow the course of these veins and their branches.

Exercise 21. Draw a diagram of the venous system, so far as observed.

The arterial system (*continued*). We shall now study the efferent branchial arteries and the dorsal aorta and its branches. The afferent arteries have already been seen; the efferent arteries lie immediately posterior to them on the gill arches. Make a cross section of a gill arch and note these two arteries; the afferent is the larger of the two. Remove the ventral wall of the pharynx and the heart. Dissect away the mucous membrane which covers the roof of the mouth and pharynx. Trace the efferent arteries dorsally to the dorsal aorta. Follow the aorta and the arteries which branch from it, as already explained (see p. 51).

Exercise 22. Draw a diagram showing the efferent branchial arteries, the dorsal aorta and its branches, so far as observed. Carefully label all.

Exercise 23. Draw a diagram of the entire vascular system.

The body muscles. Skin the side of the body. Note the great muscle which forms the entire side and extends from the head to the caudal fin. This complex muscle is made up of a succession of muscle segments called **myotomes** or **myomeres**, which are separated from one another by connective-tissue septa called **myocommas**. Each myotome is a plate, or lamella, between two myocommas, and consists of parallel fibers which run across from one myocomma to the other. The fibers thus are not bound together by fasciæ as in the muscles of the higher vertebrates. Note the zigzag shape of the edge of the myotome, which appears

on the surface of the body; note also that each myotome may be divided into a dorsal and a ventral half.

Exercise 24. Make an outline of the fish and draw in it a few of the myotomes and myocommas.

Cut the tail off an inch or two behind the anus and study the cut surface. The myotomes appear here in groups of concentric circles. This appearance is due partly to the fact that the inner edge of each myotome, which is attached to the spinal column and to its dorsal and ventral processes, is much anterior in position to the outer edge which appears on the surface, and also partly to the zigzag shape of the myotomes. Cut horizontal and dorsoventral sections of the muscles and prove this.

Observe the other structures in the cross section, — the skin with the scales and the lateral line, and the spinal column with the neural arch on its dorsal side and the hæmal arch on its ventral side, the former containing the spinal cord and the latter the caudal artery and vein.

Exercise 25. Draw the cross section.

The skeletal system. The skeleton of the fish is made up of two distinct portions, — the **exoskeleton** and the **endoskeleton**. The former is of dermal origin and consists of the ctenoid scales and the teeth. The scales are imbedded in the dermis, or inner layer of the skin; covering them on the outside is a thin layer of the dermis and all the epidermis, which, however, are often broken through by the sharp posterior tips of the scales. Of dermal origin are also the membrane bones which take part in the formation of the skull. These are, however, so intimately associated with the other bones of the skull, which belong to the endoskeleton, that they will be studied with them.

Pull out several scales, including some from the lateral line, and study them with the aid of a lens or microscope. Note the parallel lines of growth. In the scales from the lateral line note the minute canal on the inner side of the scale and the pore by which it communicates with the outside.

Exercise 26. Make a sketch of a scale from the lateral line.

The **endoskeleton** forms the bony and cartilaginous framework of the body. It may be divided into (1) the **axial skeleton,** which includes the skull and the vertebral column, with the ribs; and (2) the **appendicular skeleton,** which includes the skeleton of the paired and the median fins.

To prepare the endoskeleton for study remove all the viscera; immerse the animal in hot water in order to soften the muscles, and then carefully remove them from the skeleton. Separate the bones from one another as little as possible at first, but leave enough of the ligaments to bind them together. Be very careful not to remove any of the bones of the head, some of which are small and easily lost. If any of the bones are removed from the skeleton in preparation, they must be carefully preserved. It is of great practical use to have a dried skeleton at hand for comparison during the dissection. It is not necessary that this skeleton be thoroughly cleaned and mounted, but any skeleton that has been dried after the muscles have been removed will answer the purpose.

The axial skeleton; the vertebral column and the ribs. The vertebral column consists of a succession of bony vertebræ closely connected by intervertebral ligaments. They are deeply biconcave or amphicœlous; the two concavities are joined by a central canal and all these spaces are filled with the jellylike notochord. The notochord thus forms a continuous structure which runs the length of the vertebral column.

The vertebral column may be divided into two regions,— the **trunk region,** in which ribs are present, and the **caudal region,** in which they are absent. Each trunk **vertebra** is composed of a biconcave **body** or **centrum,** from the dorsal side of which arises the **neural arch,** and from the ventrolateral side projects a pair of long **hæmal processes.** The neural arch is composed of a pair of **neural processes** and a long median **neural spine**; it incloses the spinal cord. Projecting from the lower part of the anterior edges of the neural processes is a pair of small articular processes called the **prezygapophyses**; they articulate with a pair of projections from the posterior end of the centrum of the next vertebra called the **postzygapophyses.**

The **ribs** are long, slender bones which project from the hæmal processes. The first four or five vertebræ have no hæmal processes and the ribs project from their centra. The ribs of teleosts are not homologous to those of the higher vertebrates, but represent the distal ends of the hæmal processes. Extending from the ribs is also a series of long, slender bones which lie in the myocommas and may be homologous to the ribs of the higher vertebrates; they are called **intermuscular bones.**

The caudal vertebræ differ from the others in that the hæmal processes meet in the midventral plane and fuse, forming a hæmal spine and inclosing a space—the hæmal canal—in which lie the caudal vein and artery; they also do not bear ribs.

Count the trunk and caudal vertebræ. Note how the former grade into the latter. The spinal column ends posteriorly with a fan-shaped bone called the **urostyle,** which supports the caudal fin.

Exercise 27. Draw a posterior and also a side view of one of the trunk vertebræ; draw the same views of a caudal vertebra.

Make a sagittal section of a vertebra. Examine the concavities with the aid of a lens and note the lines of growth. The centrum increases in size by the addition of successive layers of bone to the outside, each of which is a little larger than the previous one and hence overlaps it; the biconcave shape is the result of this method of growth.

Exercise 28. Draw the section on a large scale, showing these features.

The skull. The skull is composed of two portions, — the **cranium,** which protects the brain and the special sense organs, and the **visceral skeleton,** which surrounds the anterior end of the alimentary canal and consists of the framework of the jaws and gill arches. These two portions of the skull have had a very different origin and are different in character and appearance. The cranium forms the entire dorsal half of the skull, and its

constituent bones and cartilages are for the most part immovably knit together, so that they form a single compact whole. The visceral skeleton forms the ventral half of the skull, and its bones and cartilages are mostly loosely joined with one another and with the cranium.

The visceral skeleton. Without at first removing any of its parts we shall now study the skeleton of the jaws and the gill arches. The visceral skeleton is made up of a series of seven arches called the **visceral arches**, which surround the mouth and pharynx. In the embryonic teleost, as in the adult elasmobranch, these arches are composed entirely of cartilage. This cartilage is for the most part replaced by bone as the young teleost becomes older, so that the visceral arches become bony structures. Other bones also make their appearance in connection with them which do not develop in the cartilage but in the skin and in connective-tissue membranes covering the skull, and are called **membrane bones**. Thus, as to the method of origin, two kinds of bone are present in the skull, **cartilage bones** and **membrane bones**.

Each visceral arch is a paired structure consisting of a right and a left side which meet in the midventral plane. Each side is also made up of several segments which fall approximately into a dorsal and a ventral half.

The visceral arches may be divided into two groups, — an **anterior group**, consisting of the first two arches, which, with certain membrane bones, form the skeleton of the jaws, the tongue, and the operculum; and a **posterior group**, consisting of the last five arches, which support the gills and are called the gill or branchial arches. Identify these two groups.

We shall first study the anterior group. The first visceral arch is the **mandibular arch**. The dorsal and ventral halves of it, together with certain membrane bones, form the skeleton of the upper jaw, the roof of the mouth, and the lower jaw. The second visceral arch is the **hyoid arch**, the dorsal half of which enters into relation with the mandibular arch and becomes the suspensorium of the jaws, i.e. the connecting link between them and the cranium, while the ventral half forms the support of the tongue and bears the opercular bones and the branchiostegal rays.

The mandibular arch. Identify the following bones forming the lower jaw, the ventral half of this arch. At its proximal end is the large **articular bone**, by means of which it articulates with the quadrate bone of the upper jaw. This is a cartilage bone, being an ossification of the posterior end of Meckel's cartilage. In the elasmobranch Meckel's cartilages form the lower jaw. In the teleost they are also present, forming the axis of the lower jaw, their posterior ends only having ossified. The forward and middle surfaces of the lower jaw are formed on each side by the large **dentary bone**, which bears teeth. This is a membrane bone, having formed around Meckel's cartilage, which is visible in a groove on its inner surface in a fresh skull. A small additional membrane bone — the **angular** — is present at the hinder end of the jaw.

Identify the bones of the upper jaw. Forming the forward end and the lateral margins of this jaw are two pairs of membrane bones, — the **premaxillæ** and the **maxillæ**. The former bear teeth and meet each other in the middle line in front; the latter are without teeth, being a pair of flattened rods back of the premaxillæ, with which their anterior ends articulate.

The hinder end of the upper jaw is made up of a series of paired bones which have ossified in or around the pterygoquadrate cartilage, which forms the embryonic upper jaw of the teleost and the adult upper jaw of elasmobranchs. The **quadrate bone** is a large triangular bone at the hinder end of the upper jaw on each side, with which the lower jaw articulates. The **metapterygoid** is a large bone lying just above the quadrate and back of the orbit. The **ectopterygoid** is an elongated bone which projects in front of the quadrate. The **endopterygoid** is a thin plate above the anterior end of the ectopterygoid and forming a part of the roof of the mouth. In front of the last two bones is the **palatine**, which helps form the roof of the mouth and bears teeth.

Of these bones the quadrate and the pterygoids are ossifications of the pterygoquadrate cartilage; the palatine is a membrane bone which forms around the anterior end of this cartilage.

Surrounding the orbit and forming its margin on all except the dorsal side is a row of membrane bones called the **suborbitals**, which are very easily lost in the cleaning. The most anterior one is a large bone between the orbit and the maxilla, on the surface of which will be seen radiating canals belonging to the lateral-line system of sensory canals.

The hyoid arch. The dorsal half of this arch forms the suspensorium. It is formed by the **hyomandibular** and the **symplectic bones**. The former is a large bone which extends from the cranium ventrally, back of the metapterygoid to the symplectic; the latter is a small bone which lies just dorsal to the hinder end of the quadrate; the jaws are thus joined with the cranium.

The ventral half of the arch is formed by a row of bones, on each side, which extend ventrally from the junction of the symplectic and the hyomandibular and are called collectively the **hyoid bones**. These are the **interhyal**, **epihyal**, **ceratohyal**, and the two **hypohyal bones**; of which the epihyal and ceratohyal are the largest and bear the branchiostegal rays. In the middle area between the right and left sides of the hyoid arch is the **basihyal bone**, which supports the tongue.

Articulating with both the dorsal and ventral halves of the hyoid arch on each side are bony plates and rods which support structures guarding the openings of the gill slits: these are the **opercular bones** and the **branchiostegal rays**. There are four opercular bones: the **preopercular** lies along and back of the hyomandibular and symplectic bones; the **opercular** is a broad bone just back of the preopercular and the hyomandibular, the hinder border of which is drawn out into a long spine; the **interopercular** and **subopercular** lie along the ventral borders of the preopercular and the opercular respectively.

Articulating with the ventral half of the hyoid arch are seven slender arched bones, the **branchiostegal rays**, which support the branchiostegal membrane. Note with which bones they articulate.

Exercise 29. Draw a semidiagrammatic view of the side of the skull on a scale of 2, and carefully label all the bones just mentioned.

Remove the opercular bones and the lower jaw. Remove the suborbital bones. The lateral aspect of the gill arches, the hyoid bones with the branchiostegal rays, the hyomandibular, symplectic, and the pterygoids will be seen. Carefully clean them with a brush but do not remove them.

Exercise 30. Draw this aspect, showing these bones.

Disarticulate and remove the five gill arches and the hyoid arch from the body. In the midventral area and joining these arches is a row of median bones called the **basibranchials**, or **copulæ**; the copula of the hyoid arch is the basihyal, which supports the tongue and has already been described. The first, second, and third gill arches each articulates with its median basibranchial by means of a short bone called the **hypobranchial.** The next bone in each arch is the largest and forms the main part of it; it is called the **ceratobranchial.** The fourth arch articulates by its ceratobranchial with the basibranchial; the fifth arch consists of a ceratobranchial alone and bears teeth.

The next bone dorsally in all except the fifth arch is the **epibranchial.** This is followed by the **pharyngobranchial,** which joins its fellow of the opposite side in the middorsal line. In the second, third, and fourth arches the pharyngobranchials are broad plates which bear teeth; in the first arch the pharyngobranchial is a small bone which joins that arch with the cranium. Note which of these bones bear **gill rays.**

Exercise 31. Make a drawing of the ventral aspect of the gill and hyoid arches on a scale of 2; carefully label their various parts.

Exercise 32. Make a drawing of the roof of the mouth and carefully label all the bones already studied.

Remove the premaxillary, maxillary, palatine, pterygoid, quadrate, symplectic, and hyomandibular bones, and study the cranium.

The **cranium** is a complicated structure, made up of a large number of bones and cartilages. The bones are so tightly bound

together that the sutures are often indistinguishable until the skull has been boiled or soaked a long time in an ammonia solution; the cartilages are the remains of the chondrocranium, the primitive cartilaginous cranium which forms the skull of the young animal, and in the adult fish is partly replaced by bone. As in the case of the visceral portion of the skull the bones of the cranium fall into two categories, — the **cartilage bones**, which develop in and replace the primitive cartilage, and the **membrane bones**, which develop independently of the cartilage in connective-tissue membranes and in the dermis of the skin.

Two distinct regions are present in the cranium: (*a*) the **cranium proper**, which is the brain case and comprises the bones and cartilages in the medial portions of the skull; and (*b*) the **capsules** of the **special sense organs**, which protect the optic, auditory, and nasal organs.

Observe the general character of the **cranium**. Note the small brain cavity and the **foramen magnum**, the opening at the hinder end of the cranium by which the spinal cord enters it. Note the **orbit**, which occupies a large space on the side of the cranium; the portion of the cranium in front of it forms the **nasal capsule**; that back of it on each side is the **auditory capsule**. Note the two flat spines which project back of the auditory capsule on each side.

Study the posterior aspect of the cranium. The hinder end is formed of four **occipital bones**, all of which are cartilage bones. The **basioccipital** is ventral; its concave posterior surface articulates with the centrum of the first vertebra. The two **exoccipitals** inclose the foramen magnum between themselves; each bears a broad articular surface which meets a corresponding one on the neural arch of the first vertebra. The foramen of the vagus nerve is in the exoccipital on each side. The **supraoccipital** is dorsal and bears a broad median spine. On each side of these bones and forming the postero-lateral part of the cranium is the auditory capsule.

Exercise 33. Draw the hinder end of the skull on a scale of 2, showing outlines of these bones.

Study the dorsal aspect of the cranium. Extending in front of the supraoccipital are the two large **frontal bones**; these are membrane bones which form the greater part of the roof of the skull and the medial walls of the orbits. Immediately back of the frontal bone on each side is the small, irregular **parietal**, also a membrane bone.

The **auditory capsule** is formed of an intricate complex of bones at the postero-lateral corner of the skull. From the hinder end of the capsule two prominent spinelike processes project, these processes on the two sides, together with the median supraoccipital spine, forming the five prominent projections at the hinder end of the skull.

Of the two lateral processes the more dorsal is the **epiotic process**; it is formed by the small **epiotic bone**, which lies lateral to the supraoccipital and behind the parietal. The more ventral process is the **parotic process**. It is formed by two bones, — the more dorsal being the **pterotic**, the more ventral the **opisthotic**, — the latter of which contains the foramen of the glossopharyngeal nerve. Directly in front of the opisthotic is the **proötic bone**, through the anterior border of which go the trigeminal and facial nerves, and directly above which is the **sphenotic**. These five **otic bones** are all cartilage bones which form the auditory capsule.

Just in front of the proötic and sphenotic are two cartilage bones, — the **orbitosphenoid** and the **alisphenoid**, — the former being the more ventral of the two; they belong to the cranium proper, lying in the lateral wall of the brain case, and are not seen from above.

In front of the frontals and forming the anterior end of the cranium are the paired **nasals**, which form the roof of the nasal capsule.

Exercise 34. Draw the dorsal aspect of the cranium on a scale of 2.

Study the ventral aspect. Three bones form the medial portion of the ventral wall of the cranium, — the **basioccipital** at the hinder end, the **vomer** at the forward end, and the long slender

parasphenoid or **parabasal** between. The latter two are membrane bones; the vomer bears teeth and forms the ventral wall of the nasal capsule.

In front of the orbits and directly above the vomer are the **median ethmoid** and the two **lateral ethmoids**, which are cartilage bones forming the anterior end of the cranium proper and the hinder end of the nasal capsules.

The cranium, as we have already seen, is composed of the cranium proper and the special sense capsules. The former, which is the brain case, contains the following bones: the occipitals, parietals, frontals, sphenoids, ethmoids, and parabasal. The sense capsules inclose the auditory, optic, and olfactory organs. The auditory capsule is made up of the otic bones. The optic capsule does not ossify, but remains largely membranous; the sclera of the eyeball, however, contains cartilage, and certain membrane bones — the suborbitals — appear around the orbit. The nasal capsule contains the nasals and the vomer; the ethmoids also enter into relations with the hinder part of it.

Exercise 35. Draw the ventral aspect of the cranium on a scale of 2, showing outlines of the bones.

Exercise 36. Draw the lateral aspect.

Boil the cranium until the bones can be separated from one another, and study them carefully.

The appendicular skeleton. Four **median fins** are present, — an anterior and a posterior dorsal fin, a ventral fin, and a caudal fin. The framework of the two dorsal fins and that of the ventral fin are essentially alike; each consists of a series of elongated bones, the **basals** and **radials**. The former are long, flattened plates which lie imbedded between the muscles of the right and left sides of the body, alternating with the hæmal and neural spines. Articulating with the outer end of each of these bones is a radial, or fin ray, a straight bony rod. Note the two kinds of fin rays, the sharp stiff ones, and the jointed flexible ones. The anterior basal does not bear a radial. The caudal fin is without basals,

the radials joining directly with the urostyle and the neural and hæmal spines.

Exercise 37. Draw the skeleton of a dorsal fin and that of the caudal fin.

The paired fins. The **pectoral fin** consists of about fifteen fin rays and four small basals, the latter articulating with the **pectoral girdle.** This structure is formed of several bones, of which two — the **scapula** and **coracoid** — articulate with the basals, the former of these bones being dorsal to the latter. These bones are cartilage bones and represent the pectoral girdle of the elasmobranch. In addition to these are a number of membrane bones which join the fin with the cranium. The **cleithrum**, or so-called clavicle, is the largest of these and extends upward from the anterior border of the scapula and coracoid. Its dorsal end joins the **supracleithrum**, which in turn is joined with the skull by the V-shaped **posttemporal.**

Exercise 38. Draw the pectoral fin and girdle.

The pelvic fins. Each of these consists of about five radials. At their proximal ends they articulate with a large plate which represents the fused basals. These two plates lie alongside of each other in the median area; no pelvic girdle is present.

Exercise 39. Draw the pelvic fins.

CHAPTER II

AMPHIBIANS

A URODELAN AMPHIBIAN. NECTURUS

Necturus, or the mud puppy, is one of the largest of the salimanders. It is common throughout the central portions of the country, where it lives in lakes and streams upon small fishes and other animals. It is one of the most primitive of the urodeles. The external gills — which in most amphibians are larval characters and disappear as the animal becomes adult — are retained throughout life by Necturus; it never leaves the water.

Three specimens will be needed for a complete dissection, — one for the study of the external characters and the viscera, including the heart and the principal blood vessels; one for the dissection of the entire vascular system; and one for the skeleton. A five per cent solution of formalin should be used to preserve them in.

Place the animal, alive if possible, on a dissecting board or in a large pan and observe its form and color. The body is cylindrical in shape, flattened dorsoventrally except at the hinder end, which is compressed laterally and surrounded by a dorso-ventral fin. The tail is the principal organ of locomotion. ...urus; small, weak legs, with the clawless toes, are only of use ... and to the animal walks; while it is swimming they are held ... the sides of the body.

The skin of Necturus is smooth, as in most amphib... without bony or horny scales or other hardened inte... structures, such as are possessed by all the other gro... e of 2 or 3, tebrates. It is, however, provided with numerous ... l lips. tary glands which secrete a protective but nonpois... Along the middle of the back a double row of thes... warm water be seen when the skin is removed. ...nder a bell jar

Note the color of the animal and the variation of color on the dorsal and ventral sides. The animal is well fitted by its color for a life in the dimly lighted waters in which it is found.

The body of the animal may be divided into three regions, — the **head**, the **trunk**, and the **tail**. The neck region, which is wanting in fishes and is so characteristic of land vertebrates, is just beginning to make its appearance in amphibians. A distinct neck is wanting, but a cervical vertebra is present with which the skull articulates.

The head. This body division is bluntly triangular in shape and is very flat and broad. The **mouth** is rather small and the **lips** are prominent. At the sides of the mouth note how the upper lip dovetails into a fold of the lower lip. The two **nostrils** are at the anterior end of the head and widely separated from each other; each can be tightly closed by a fold of skin. The **eyes** are small and do not project. No eyelids are present; the skin passes without interruption over the eyes, but is transparent in front of them. The ear, as in fishes, is entirely within the skull, no portion of it appearing on the surface. Integumental sense buds, such as occur on the head and in the lateral line of fishes, are present on the head and body of Necturus, but will hardly be seen.

The posterior part of the head is marked by a ventral transverse fold of the skin and also by three pairs of **gills**. These gills are not homologous to the gills of fishes, but are projec-
of the outer integument; note carefully their character
ape. Between the first and second and the second and
lls on each side is a **gill cleft**, a slitlike opening into the
. Probe these clefts. Necturus has a twofold method
ation, — by means of lungs, and through the entire
face of the body and the gills. Inasmuch as the
er leaves the water, the latter method is the more
ne.

and the **tail** pass gradually into each other. They
external segmentation, but the muscle segments
detected through the skin. The trunk bears the
short distance back of the hinder appendages in

the ventral surface is the large **anus**, the opening of the cloaca. Note its shape; its lips are often swollen in consequence of the absorption of water by the cloacal glands.

The appendages. The two pairs of legs are nearly of the same size and are widely separated from each other. Each leg is composed of three divisions, — a **proximal**, a **middle**, and a **distal division.** In the fore limb these segments are the upper arm, the forearm, and the wrist and hand respectively; in the hind limb they are the thigh, the shank, and the ankle and foot.

Note the position of the limbs with reference to the trunk, which in Necturus is of a primitive character. In their most primitive position the limbs of vertebrates are straight, and extend at right angles to the body. Each limb has in this position a dorsal and a ventral surface, and an anterior or preaxial and a posterior or postaxial surface. If the human arm be extended straight out from the body with the thumb up, it will assume this primitive position; the back of the hand will be dorsal, the palm ventral, and the thumb will be preaxial or anterior in position.

The first modification of this primitive position, which occurred as a result of locomotion on a hard surface, was the bending of the middle segment of the leg ventrally and the distal segment more or less dorsally. The proximal segment retained its primitive position; the middle segment bent downward; and the distal segment assumed more or less its original position again, at right angles to the body but in a different plane. This is approximately the position the limbs have in Necturus; it enables the limbs to raise the trunk above the ground and to propel it slowly forward.

Exercise 1. Draw the dorsal aspect of the animal.

Exercise 2. Draw the ventral aspect.

Exercise 3. Draw a side view of the head on a scale of 2 or 3, showing accurately the gills, eyes, nostrils, and lips.

The animal may be killed by immersing it in warm water (about 43° C. or 110° Fahr.) or by putting it under a bell jar

with a wad of cotton soaked in chloroform or ether. While under the influence of the anæsthetic a large quantity of slime usually exudes from its skin; this slime must be scraped off.

The mouth and pharynx. Cut back through the angle of the jaw on each side until the lower jaw can be laid back and the mouth and pharynx fully exposed.

The mouth and pharynx form a single large cavity, which extends back to the opening of the œsophagus, the pharynx being that part of it which contains the respiratory openings, i.e. the glottis and gill clefts. Note the large **lips**; also the two rows of **teeth** in the upper jaw and the single row in the lower jaw which fits between them. In the floor of the mouth is the short **tongue**, supported by the large cartilaginous bars which form the hyoid apparatus. These bars can be felt through the mucous membrane of the mouth. Just back of this apparatus and joined with it are the **gill arches**. Note the **gill clefts** and probe them. Between the gills in the median line is a small longitudinal slit, the **glottis**, the opening into the lungs. It is bounded on the sides by the delicate arytenoid cartilages, which form the primitive larynx. On the roof of the mouth the **posterior nares** will be found between the lateral rows of teeth; they are a pair of small openings which form the communication between the pharynx and the nasal capsules. Probe them.

Exercise 4. Draw a sketch of the mouth and pharynx, showing both floor and roof.

The internal organs. Open the body cavity in the following way. Place the animal on its back in the dissecting pan or on a dissecting board, with the head away from you, and fasten it there firmly by means of a large pin at each end and one through each leg. Then with a sharp scalpel and scissors make an incision through the body wall, a short distance to one side of the median line, from the hinder end of the head to the anus, taking care not to cut too deeply, especially at the forward end where the heart and its great vessels lie near the ventral surface. The pectoral girdle and also the pelvic girdle will be cut through by this incision. Pull the two flaps of the body wall apart, but

without cutting or disturbing any organs within, and examine the viscera as they lie in the body cavity.

The **body cavity** is divided into two very unequal divisions, the larger and posterior of which is the **abdominal cavity**; this is lined by the **peritoneum**, the glistening membrane on its inner surface, and contains the larger part of the viscera. The anterior division is the **pericardial cavity**; it is lined by the **pericardium** and is very small, containing only the heart. These two divisions are separated by the **false diaphragm**, which is composed of the posterior wall of the pericardium and the anterior wall of the peritoneum.

Note that the organs in the **abdominal cavity** are attached to its walls by delicate membranes. These are the **mesenteries**, which are folds of the peritoneum. This membrane forms a closed sac lining the abdominal cavity; the various organs of this cavity project into the sac and are suspended in peritoneal folds which form the mesenteries and extend into its interior from its walls.

The most prominent organ in the abdominal cavity is the **liver**, an elongated, dark-colored body which is attached to the ventral wall of the cavity by a median, vertical mesentery. At the right of it (the animal's left) is the **stomach**, which is of about the same length as the liver, and at the left of the stomach is the elongated, dark-colored **spleen**. Between the hinder end of the stomach and the liver will be seen the cream-colored **pancreas**. Behind the stomach are the coils of the intestine, attached to the dorsal body wall by an extensive mesentery. Between the stomach and spleen and the dorsal body wall may be seen the narrow, cylindrical left **lung**. At the posterior end of the abdominal cavity is the **urinary bladder**, a large sac, which may appear large and distended or very much contracted.

The heart and the pericardial cavity. Carefully cut away the body wall over the heart and expose the pericardial cavity. The heart is composed of five divisions, a single ventricle, two auricles, the sinus venosus, and the truncus arteriosus.

The **ventricle** is the conical, posterior portion of the heart. The **auricles** are a pair of thin-walled and dark-colored sacs in

front of the ventricle; they are not completely separated from each other. The **sinus venosus** is a large, thin-walled sac which lies dorsal to the ventricle and is in communication with the right auricle; it will be seen by turning the ventricle to one side. The **truncus arteriosus** is the forward continuation of the ventricle; it is composed of two portions, — the **conus arteriosus**, which is immediately in front of the ventricle, and the **bulbus arteriosus**, the enlarged anterior portion of the truncus which is the beginning of the ventral aorta. The muscular walls of the bulbus exert a steady pressure on the blood passing through it, so that the latter goes forward with a steady flow instead of by beats.

At its anterior end the bulbus continues forward as the **ventral aorta**; this vessel soon splits into two pairs of arteries which carry the blood to the gills; the posterior pair goes to the second and third pairs of gills, and the anterior pair to the first pair of gills.

Exercise 5. Draw an outline of the animal and in it outlines of the internal organs as they lie in the abdominal and pericardial cavities; carefully label all.

The digestive system. This is composed of the mouth, pharynx, œsophagus, stomach, small intestine, liver, pancreas, large intestine, and cloaca.

Observe the great length of the **stomach**. Its anterior or **cardiac end**, and the short **œsophagus**, which joins it with the pharynx, are concealed by the heart. Cut out the heart. The posterior or **pyloric end** of the stomach is marked by a constriction and is situated near the posterior end of the liver.

The **intestine** extends from the stomach to the cloaca. Two regions may be distinguished, — the **small intestine** and the **large intestine**. The former makes up the greater part of the intestine; its anterior end, which may be called the **duodenum**, bends forward so as to lie parallel with the stomach for a short distance, and in the angle thus formed lies an irregularly folded organ, — the **pancreas**. The large intestine is somewhat thicker than the small intestine, and joins it with the cloaca at the hinder end of the abdominal cavity.

Extend the intestine as much as possible without cutting the mesentery which joins the entire digestive tract with the dorsal body wall. Observe the numerous veins which lie in this mesentery; they belong to the **hepatic portal system** and carry blood from the wall of the intestine to the liver. The **intestinal veins** will be seen running from the wall of the intestine to the large **mesenteric vein**, — a longitudinal vessel which extends from the hinder part of the abdominal cavity to the liver.

Observe the **cloaca**. Probe through the anus into it. The cloaca is the common receptacle into which the genital and urinary ducts, as well as the intestine, empty their products.

Study the **liver** and **pancreas**. Observe the lobes of the liver and the position of the spherical **gall bladder** under the right lobe. The **bile duct** joins the liver with the intestine; it emerges from the gall bladder, receives a branch from the liver, and passes through the pancreas to the bend of the duodenum. By squeezing the gall bladder with forceps the dark-green bile can often be forced into the bile duct.

The **pancreas** is an elongated organ lying between the duodenum and the stomach; its secretion is poured into the bile duct through numerous fine canals.

Partially imbedded in the dorsal surface of the liver will be seen the large **postcaval vein**; it runs along the entire length of the liver and receives from it numerous small **hepatic veins**. The postcaval vein carries blood from the middle and hinder portions of the body to the heart.

Exercise 6. Draw a semidiagrammatic sketch of the digestive system, with the liver, the pancreas, and the mesentery.

Cut the mesentery joining the lungs with the stomach. Remove the stomach, intestine, liver, and pancreas from the body; leave the lungs in the body.

The urogenital system. The urinary and genital organs, although very different in function, stand in close relation to each other and will be described together.

The **urinary organs** consist of a pair of **kidneys**, a pair of **ureters** or **Wolffian ducts** which join the kidneys with the cloaca, and a

urinary bladder. The kidneys are narrow and greatly elongated bodies which lie in the hinder part of the abdominal cavity close to the dorsal body wall. The ureter is a convoluted tube which lies against the outer edge of each kidney and opens into the dorsal side of the cloaca. The urinary bladder is a large sac which opens into the ventral side of the cloaca opposite the openings of the ureters. Note the mesentery which joins it with the ventral body wall.

The male genital organs. The **testes** are a pair of yellowish, cylindrical bodies, each of which is attached to the dorsal body wall by a mesentery. Delicate tubes, the **vasa efferentia,** connect the testis with the median border of the kidney on each side. Hold the mesentery to the light and note these vessels, which are suspended in it. Spermatozoa are produced in the testes and pass through the vasa efferentia into the kidneys, whence they find their way into the Wolffian ducts or ureters. These organs thus perform the double function of conducting to the outside both the urine and the spermatozoa; on this account they have received a special name, and are also called **ducts of Leydig.** It is only in elasmobranchs and amphibians that Leydig's duct is present.

The female genital organs. The **ovaries** are a pair of irregular, elongated bodies which lie in the body cavity, attached to its dorsal wall by mesenteries. They vary in size with the sexual condition of the animal. The ova are emitted into the body cavity by the rupture of the wall of the ovaries, whence they pass to the outside through the **oviducts,** or **Müllerian ducts.** These are a pair of thick-walled, convoluted tubes which extend from the forward end of the abdominal cavity to the dorsal wall of the cloaca. The hinder end of each is expanded and forms the **uterus,** — a receptacle in which the ova are stored at the time of laying.

Observe carefully these organs and note their exact position. Slit open the cloaca and find the mouths of the ureters, and of the oviducts if the animal be a female.

Exercise 7. Draw a semidiagrammatic sketch of the urogenital system, showing accurately the position of the urogenital organs.

The respiratory system. The principal organs of respiration are the outer **skin** and the **gills.** The **lungs,** which also aid in respiration, are a pair of very long cylindrical sacs extending back in the abdominal cavity from the ventral wall of the pharynx. Note that the two lungs meet immediately before they open into the pharynx through the **glottis**: a windpipe or trachea is thus absent. Slit open one of the lungs and note the thinness of the walls. Examine carefully the structure and mechanism of the glottis.

Exercise 8. Draw the lungs.

Remove the lungs and the urogenital organs from the body.

The nervous system. This system is composed of the following divisions: (1) the **central nervous system,** consisting of the brain and the spinal cord; (2) the **peripheral nervous system,** consisting of the cranial and spinal nerves and the sympathetic nervous system; and (3) the **special sense organs.**

The special sense organs; the auditory organs. The ear consists of a membranous labyrinth or inner ear alone, no external opening being present. It is relatively of large size and may be studied in this dissection. The auditory capsule, which incloses the labyrinth on each side, is composed largely of cartilage and forms the hinder part of the skull.

The membranous labyrinth is made up of the following parts: (*a*) the **vestibule,** an irregular sac occupying the ventral and middle portions of the capsule and formed of two main divisions, the upper **utriculus** and the lower **sacculus**; (*b*) the **semicircular canals,** three delicate tubes which rise from the utriculus and extend to the dorsal wall of the capsule; and (*c*) the **ductus endolymphaticus,** a delicate tube which passes dorsally from the sacculus.

The auditory capsules will be recognized from the outside as a pair of prominences at the hinder end of the skull. Remove the skin and muscles from the dorsal side of the skull and carefully shave off the hard bone and the cartilage which form the roof of one of the auditory capsules. The semicircular canals will first come into view. Two of these are medial in position

and one lateral. The two medial canals are known as the **anterior** and the **posterior vertical canals.** The anterior one is the larger; its forward end, close to its junction with the vestibule, is enlarged and forms the **ampulla.** The posterior canal has an ampulla at its hinder end. The lateral canal is called the **horizontal canal**; its ampulla, which is at its forward end, is close to that of the anterior vertical canal.

The sacculus, which forms the ventral portion of the vestibule, contains a large white **otolith.** At its hinder end is a small projection called the **lagena,** which is homologous to the cochlea of higher vertebrates.

Exercise 9. Draw the parts of the ear so far as observed.

The central nervous system. Remove the skin and muscles from the dorsal side of the head and the anterior end of the trunk. Carefully shave off the bone and cartilage forming the roof of the skull and expose the brain. Remove in the same way the dorsal portion of the neural canal and expose the spinal cord. Remove the membrane (the dura mater) which covers the brain.

Without removing or disturbing it, study the dorsal surface of the brain. It is made up of five regions of very different size, — the cerebrum, thalamencephalon, the optic lobes or midbrain, the cerebellum, and the medulla oblongata.

The anterior and largest division of the brain is the **cerebrum,** which is composed of two **hemispheres**; no distinct olfactory lobes are present. Back of the cerebrum is a large median structure made up of the **thalamencephalon** and the **midbrain,** no line of demarcation between them being present. Projecting forward from the thalamencephalon between the hemispheres is the large **pineal body,** or **epiphysis.**

Directly continuous with the midbrain posteriorly and separated from it by a shallow groove is the **cerebellum,** a narrow, transverse ridge which forms the dorsal portion of the fourth division of the brain. Immediately back of it is the **medulla oblongata,** the hindermost division, which is continuous with the spinal cord. On its dorsal surface is a triangular depression, —

the **fossa rhomboidalis**, — which marks the position of the fourth ventricle of the brain.

Exercise 10. Draw the dorsal aspect of the brain and a portion of the spinal cord on a scale of 2 or 3.

The cranial nerves. Ten pairs of nerves spring from the brain and pass to the organs and tissues of the head and the anterior part of the trunk. Cut away the side of the skull and expose the side of the brain; find the cranial nerves.

The first pair of cranial nerves are the **olfactories**; they are large nerves which pass directly forward from the anterior end of the hemispheres to the nasal capsules, in some cases branching before they reach the capsules. The second pair are the **optic nerves**; these nerves are small, and will be seen emerging from the brain just back of the cerebrum and passing to the orbits. The third nerve — the **oculomotor** — is a very small, threadlike nerve which arises on the ventral surface of the brain beneath the midbrain on each side, and passes forward to the orbit, where it supplies the muscles of the eyeball. The fourth cranial nerve, the **trochlear**, and the sixth, the **abducens**, are wanting in Necturus, both being incorporated in the fifth nerve.

The fifth cranial nerve — the **trigeminus** — is a large trunk which passes forward a short distance and then expands in the **Gasserian ganglion**, which lies against the inner wall of the skull. It then splits into two main branches, — an **ophthalmic** and a **maxillo-mandibular branch**, which pass to the outside of the skull; trace them as far as possible.

The seventh or **facial** and the eighth or **auditory** nerves spring from the brain as a single trunk, which, after sending off a large branch to the Gasserian ganglion, divides into two nerves, — the facial and the auditory. The former soon splits into two branches; the latter at once enters the auditory capsule.

The ninth and tenth nerves — the **glossopharyngeal** and the **vagus** — spring from the brain immediately back of the facial and auditory trunk by three roots and at once unite to form

a single large nerve. This passes back a short distance and then expands to form a large ganglion, from which numerous nerves pass to the tongue, neck, and gills, and to the heart and stomach.

Observe the anterior **spinal nerves**. Each one arises from the side of the spinal cord by two roots, — a dorsal and a ventral root, in the former of which is a ganglion. These roots pass out of the neural canal by the foramina between the vertebræ.

Exercise 11. Draw the cranial nerves and the first two or three spinal nerves so far as they have been observed.

The ventral surface of the brain. Carefully remove the brain from the skull, float it in water, and study its ventral surface. The large paired **hemispheres** will be seen and back of them the median **thalamencephalon**, from which the small **optic nerves** and the **infundibulum** proceed. The latter is a large median projection just back of the optic nerves which bears at its distal end a small body called the **pituitary body**, or **hypophysis**. This structure rests in a depression in the ventral wall of the skull and is apt to be torn away when the skull is removed. Back of the infundibulum are the **crura cerebri**, two swellings which join the medulla; they form the ventral portion of the midbrain. Note the midventral groove in the medulla and the spinal cord.

Exercise 12. Draw the ventral aspect of the brain on a scale of 2 or 3.

The cavities of the brain and spinal cord. The brain and spinal cord are hollow structures. In the center of the latter is a narrow passage called the **central canal**, while the brain contains a series of large spaces of various sizes. In the medulla is the broad, shallow cavity called the **fourth ventricle**. Its dorsal roof is not composed of nervous matter but is vascular, and hence dark colored. The cavities of the hemispheres are called the **lateral** or the **first** and **second ventricles**. These are joined with

each other and also with the small median cavity of the thalamencephalon, which is called the **third ventricle**, by a small opening called the **foramen of Monro.** Joining the third ventricle with the fourth is a median canal called the **aqueductus Sylvii**, with which are connected a pair of large cavities situated in the optic lobes or midbrain and called the **optic ventricles.**

The fourth ventricle has already been seen. The lateral ventricles are found by removing the dorsal wall of the hemispheres, and the optic ventricles by removing the dorsal wall of the optic lobes. The median spaces are not so easy to find, but may be seen by splitting the brain exactly in the sagittal plane.

Exercise 13. Draw a diagram showing the cavities of the brain.

The **vascular system** is made up of the following organs: (1) the **heart**; (2) the **arteries**, which carry blood to the gills, the lungs, and the tissues; (3) the **veins**, which return blood to the heart; and (4) the **capillaries.**

The heart. The divisions of the heart have already been observed and its ventral aspect studied (see page 69).

The veins. Two systems of veins are present: (1) the **systemic veins**, which return venous blood from the various tissues and organs of the body to the sinus venosus; and (2) the **pulmonary veins**, which return arterial blood from the lungs to the left auricle. The systemic veins include (*a*) those which go directly to the sinus venosus and their branches, and (*b*) the **portal veins**, which carry blood first to the liver and kidneys, where it is distributed through capillaries and afterward collected again in other veins which take it to the heart.

We shall first study the portal veins.. Two systems of these veins are present, — the **hepatic portal system**, by which blood is carried from the digestive organs and the spleen to the liver; and the **renal portal system**, by which it is carried from the hind quarters of the body to the kidneys. These two systems are united by the **abdominal vein**, a prominent vessel which lies in the midventral line of the abdominal cavity back of the liver.

Kill a fresh animal and skin its ventral side. Note the abdominal vein, which may usually be seen through the body

wall of the hinder part of the abdominal cavity. Open this cavity by a longitudinal incision to one side of the abdominal vein.[1]

Cut the mesentery which joins the liver with the ventral body wall, — being careful not to cut the abdominal vein, which lies in it, — press the sides of the body wall to the right and left and pin them there.

The **hepatic portal system** is composed of the **hepatic portal vein** and its branches and the **abdominal vein**, — the former bringing blood from the digestive tract and the spleen and the latter from the hinder part of the body. These two veins meet near the posterior end of the duodenum, close to the dorsal surface of the liver; they are here entirely imbedded in the pancreas. The single vessel thus formed passes at once to the liver, where it breaks up into branches which distribute blood to all parts of that organ.

Follow the abdominal vein forward to the hepatic portal. Scrape away the pancreas which surrounds them, and note that the hepatic portal is formed by the meeting of three large veins, — the mesenteric, gastric, and splenic.

The **mesenteric vein** is the large longitudinal vein which lies in the intestinal mesentery; it extends the entire length of the intestine and receives numerous **intestinal veins** which bring blood from its walls. The **splenic vein** comes from the spleen. The **gastric vein** lies along the stomach and the dorsal surface of the liver.

The **renal portal system** is formed on each side of the body by the union of the **pelvic, femoral,** and **caudal veins,** which meet and form the **renal portal vein**; the system is joined with the hepatic portal system by the abdominal vein.

[1] Both portal systems may be injected through either the abdominal vein or the mesenteric vein. If the former be used, it must be injected both forward and backward; if the latter, a single injection will fill both portal systems. The systemic veins and the arteries should also be injected now. Turn the liver to the animal's left; the very large postcaval vein will be seen coming from between the kidneys and entering the liver near its middle. Inject it in both directions. The entire arterial system may be injected through the ventricle and the truncus arteriosus of the heart.

Trace this last-named vein back to the hinder part of the abdominal cavity; it will be seen to be formed by the union of two prominent veins, — the **right** and **left pelvic veins**, — one of which will have been cut by the first incision. Trace the pelvic vein backward; it is formed by the union of the **femoral vein**, which comes from the hind leg, and the **renal portal vein**, which goes to the side of the kidney. This vein enters the kidney and distributes blood throughout that organ.

Blood from the tail is brought forward by the **caudal vein**. This vein runs just beneath the spinal column of the tail to the hinder end of the abdominal cavity; here it divides into two veins, each of which goes to the side of the kidney and joins the renal portal vein.

Exercise 14. Draw the two portal systems.

The remaining **systemic veins** may be divided into two groups, — those coming to the heart from the forward part of the body and those coming from the hinder part.

The latter veins are the postcaval, the posterior cardinal, and the lateral veins. The **postcaval** is the largest vein in the body; it begins its course between the kidneys, from which it receives numerous small branches, and runs forward, just beneath the dorsal aorta, to the middle of the dorsal surface of the liver. Here it turns slightly to the right, enters the liver and runs through it to its forward end, receiving several **hepatic veins**. On leaving the liver it becomes much wider and divides into two short trunks, which at once enter the sinus venosus. Find this vein just back of the liver and trace it both ways.

Between the kidneys and the liver the postcaval receives a number of small **genital veins** from the reproductive organs and a branch from each of the posterior cardinal veins.

The **posterior cardinals** are a pair of veins which arise near the middle of the body and run forward at the right and the left of the median plane and near the dorsal body wall; in the female each posterior cardinal lies in the mesentery which joins the oviduct with the dorsal body wall on each side. A short distance in front of the anterior end of the liver each of these

veins joins a short transverse vein called the **duct of Cuvier**, which meets the widened end of the postcaval near its entrance into the sinus venosus.

The **lateral veins** are a pair of small vessels, each of which lies beneath the skin along the lateral line; they enter the duct of Cuvier.

Blood is brought from the forward part of the body by the **anterior cardinal** and the **subclavian veins.** The former are a pair of short veins which arise, on each side, by the union of the **internal** and the **external jugular veins.** The external jugular is the large vein which brings blood from the ventral wall of the mouth; the internal jugular is a much smaller vein which brings blood from the roof of the mouth and the brain. The subclavian brings blood from the arm on each side; it and the anterior cardinal meet in the duct of Cuvier.

The **pulmonary vein** brings blood to the left auricle from the lungs. It is formed by the union of the right and left pulmonary veins, which come from the right and left lungs respectively. Each of these veins is a prominent vessel which lies on the inner side of the lung. Find it here and trace it forward.

Exercise 15. Draw a diagram of these veins so far as observed.

The arteries. Two systems of arteries are present: by one of these systems blood is carried from the heart to the gills and by the other from the gills to the tissues. The pulmonary arteries belong to the last-named system.

Running forward as a continuation of the truncus arteriosus is the **ventral aorta,** a large artery which lies in the median plane between the gills. At its forward end this vessel breaks into two pairs of branches. The foremost pair are the first pair of **afferent branchial arteries,** which carry blood to the first pair of gills. The hinder and larger pair soon divides and gives rise to two pairs of arteries, the second and third pairs of afferent branchial arteries which go to the second and third pairs of gills. Find these arteries and study their relation to the gill arches.

The blood, after having passed through the gills, is collected in three pairs of **efferent arteries,** which carry it away from the

gills. Find them and note their relation to the gill arches and to the afferent arteries. The foremost efferent artery on each side gives off two arteries which pass straight forward to the head, — the smaller being the **internal carotid** and the larger the **external carotid.** The second and third efferent arteries unite and form a single vessel, which is joined with the first efferent artery by means of a short connecting artery. A short distance beyond the point of junction the single vessel thus formed gives off the large **pulmonary artery**; it then becomes the **aortal arch** and, meeting its fellow of the opposite side, forms the **dorsal aorta.** The pulmonary artery passes straight back along the dorsal side of the lung.

The dorsal aorta runs back just beneath the spinal column to the hinder end of the animal; in the tail it becomes the **caudal artery.** At regular intervals, corresponding to the vertebræ, a pair of small **spinal arteries** springs from the dorsal side of the aorta and supplies the body muscles.

A short distance back of its point of origin the aorta sends off a pair of **subclavian arteries,** which go to the fore legs. Each subclavian also gives off near its base the **cutaneous artery,** which passes back in the body wall near the midventral plane and supplies the skin with blood; the outer ends of the spinal arteries anastomose with it.

The next large artery to leave the aorta is the **gastric artery,** which supplies the stomach. Near the center of the abdominal cavity the large **cœliaco-mesenteric artery** leaves the aorta and goes to the stomach, spleen, and intestine. The intestine is also supplied with blood by the **posterior mesenteric arteries,** which are about twenty in number and branch off from the hinder portion of the aorta. In most of the higher vertebrates a single posterior mesenteric trunk is present. The numerous **genital arteries** and **renal arteries** also branch off from the hinder portion of the aorta and supply the genital organs and the kidneys. The large **iliac arteries** leave the hinder end of the aorta and go to the hind legs.

Exercise 16. Draw a semidiagrammatic sketch of the entire arterial system.

The muscular system. Remove the skin from the entire body of a Necturus. Inasmuch as the skin adheres very tightly to muscles beneath, eare must be taken not to cut the latter, especially on the lower jaw and the breast. Begin with a median incision down the back of the animal and skin toward the ventral side.

Observe the great complex muscle which forms the side of the trunk and the tail. It will be seen to be made up of a succession of muscle segments which are called **myotomes** or **myomeres** and are separated from one another by connective-tissue septa called **myocommas.** Each myotome is a plate between two myocommas, and consists of parallel muscle fibers which run across from one myocomma to the other. The body musculature of the trunk and the tail is essentially like that of the fish. In the midventral line is a white line — the **linea alba** — which divides the muscles on the right side from those on the left.

In the region of the head, the legs, and the arms, specialized muscles are present. The entire ventral surface of the lower jaw is bounded by a broad, thin muscle, the **submandibular,** the fibers of which have a transverse direction and are divided by a median tendon into two parts. Split this muscle in the median line and remove the left half so that the muscles beneath will be exposed. Two muscles will be seen, — the **geniohyoid** and the **ceratohyoid.** The former is a narrow muscle with longitudinal fibers which extends from the tip of the lower jaw to the hyoid cartilage; the latter is a thick muscle with an oblique direction which passes from the hyoid cartilage to the first gill arch.

In the region of the fore limbs will be seen the **pectorals,** a pair of fan-shaped muscles whose fibers radiate from the forward side of the arm to the midventral line; they draw the arms backward. The opposing muscles, which draw the arms forward, are the slender **procoraco-humeralis muscles.** These will be seen extending directly forward from the base of the arm to the procoracoid cartilages.

Note in this region the coracoid and the procoracoid cartilages, which are portions of the pectoral girdle; they are very thin plates which underlie the muscles just mentioned.

On the upper arm note the two muscles which appear on its ventral surface. The anterior muscle is the **flexor**, and the posterior one is the **extensor** of the forearm and hand. On the forearm note that but a single muscle is present on the ventral side; this is the **flexor** of the hand. In the higher vertebrates this muscle is divided into a number which flex the fingers separately.

In the region of the hind legs are the **femoral muscles**, a pair of fan-shaped muscles which extend from the base of the legs to the median line. Extending from the posterior border of these muscles to the anus are the **pyriform muscles.**

Exercise 17. Draw the ventral aspect of the animal, showing these muscles.

The skeletal system. This system is composed of two distinct portions, the **exoskeleton** and the **endoskeleton.** The former is but very slightly developed in Necturus, as in most amphibians. Bony or horny scales or other hardened integumentary structures, which form the exoskeleton in all other classes of vertebrates, are not present, the outer surface of the body being protected only by the secretions of the slime glands. Claws are also absent. The only exoskeletal structures present are the teeth and certain bones of the skull called membrane bones; these are, however, so closely joined with the other bones of the skull that they will be considered with them.

The **endoskeleton** consists of the bones and cartilages which form the framework of the body. It may be divided into (1) the **axial skeleton,** which includes the skull and the vertebral column and the ribs, and (2) the **appendicular skeleton,** which includes the framework of the two pairs of appendages or limbs.

We shall first study the appendicular skeleton. Each pair of appendages is composed of the two limbs and the girdle by which they are joined with the trunk, the girdle of the anterior appendages being the **pectoral** or **shoulder girdle,** that of the posterior appendages being the **pelvic girdle.**

The anterior extremities. The pectoral girdle consists of a pair of delicate triradiate structures, composed principally of

cartilage, which lie on the ventral and lateral sides of the trunk. Each half of the girdle supports an arm and consists of a single skeletal piece which is imbedded in the muscles of the trunk and is not joined with the other half or with the axial skeleton; at about the middle of it is a depression, the **glenoid fossa,** which receives the head of the humerus and forms the shoulder joint.

Each half of the pectoral girdle is made up of a dorsal portion — the **scapula** — and two ventral portions — the **coracoid** and the **procoracoid.** The scapula is composed of two distinct parts, — a narrow ventral portion, which is of bone, and a broad dorsal cartilaginous portion. The procoracoid is a narrow strip of cartilage extending directly forward; the coracoid is a broad plate of cartilage posterior to the procoracoid and extending medially. The coracoids of the two sides overlap each other, the left one being usually ventral to the right one. The coracoid lies beneath the pectoral muscle and the procoracoid beneath the procoracohumeralis muscle.

A **sternum** is present but is very slightly developed. It consists of two or more irregular, very delicate cartilages, which appear in the myocommas beneath the medial ends of the coracoids in the ventral body wall.

Observe the muscles on the dorsal side of the arm and shoulder, on the right side of the body. Determine accurately the outlines of the coracoid and the procoracoid beneath the muscles. The outlines of the scapula will also be easily determined by moving the arm back and forth. Pass a scalpel beneath the different parts of the girdle on this side and remove both girdle and leg from the trunk, taking care not to injure them.

Carefully remove the muscles from the girdle and identify the three parts and the glenoid cavity in which the humerus articulates. Note the **foramen coracoideum,** — a small hole through which a nerve passes.

Exercise 18. Draw the pectoral girdle.

Remove the muscles from the arm, but do not separate its bones from one another. The skeleton of the arm is made

up of three divisions, — a proximal, a middle, and a distal. The **proximal division**, or the upper arm, is a single bone, the **humerus**, the articular ends of which are cartilaginous; its proximal end or head articulates with the glenoid cavity. Note the difference in the form of the articular surfaces of the two ends. The **middle division**, or forearm, is composed of two bones, — the **radius** and **ulna**, — the ends of which are cartilaginous. Of these, the radius is anterior or preaxial in position; the ulna is postaxial and is prolonged at its proximal end to form the **olecranon process**, which forms the elbow.

The **distal division** includes the wrist and hand. The wrist, or **carpus**, is composed of six small cartilages, two of which form a transverse proximal row, three a distal row, while one is in the center. In the typical vertebrate carpus three bones form the proximal row, five the distal row, and one or two are in the center. In the hand of Necturus four **digits** are present, each of which is composed of a proximal bone called the **metacarpal** and two or three distal bones which are called the **phalanges**, or finger bones. In the typical vertebrate hand five digits are present, — the digit which is lacking in the hand of Necturus being the first or thumb.

Exercise 19. Draw the arm on a scale of 2 or 3, showing accurately the outline of each bone and cartilage.

The posterior extremities. The **pelvic girdle** is different in shape from the pectoral girdle. It consists of a large ventral plate, — the **pubo-ischium**, — which lies between the hind legs in the ventral body wall, and a slender rod on each side called the **ilium**, which extends from the ventral plate upward to the spinal column. The pelvic girdle, like the pectoral, is a paired structure, and is composed of three skeletal pieces on each side, — a dorsal piece and two ventral ones. The dorsal piece is the **ilium**: it is a slender rod of bone and cartilage; the ventral pieces are the pubis and ischium, which form the **pubo-ischium**, — the forward portion of that structure being the two pubes and the hinder portion the two ischia. Near the base of the ilium, on

each side, is the **acetabulum**, — the articular surface of the femur; a short distance in front of this is a small hole, the **obturator foramen**. The greater part of the pubo-ischium is composed of cartilage; a pair of bones is, however, present in the hinder or ischial portion.

The two ilia articulate with a single vertebra by means of its ribs. This vertebra, which is called the **sacrum**, is usually the nineteenth. In some cases the two ilia do not go to the same vertebra but to two successive ones.

Remove the thin layer of muscles which covers the ventral portion of the pelvis, and expose it. Be careful not to injure its anterior end, which runs to a point. Remove all the muscles in this region and expose the spinal column and the ilium. Find the articulation of the ilia with the sacrum; disarticulate the ilia and remove the pelvic girdle with the legs from the body.

Exercise 20. Draw the pelvic girdle and carefully label its various parts.

Remove the muscles from the leg, but do not separate the bones of the leg from one another. The skeleton of the leg is composed of three divisions, — a proximal, a middle, and a distal. The **proximal division**, or thigh, is a single bone, — the **femur**, — the ends of which are of cartilage; its proximal end articulates with the acetabulum and forms the hip joint. In the **middle division**, or shank, are two bones, — the **tibia** and the **fibula**, — the ends of which are cartilaginous, the tibia being anterior or preaxial in position.

The **distal portion** is composed of the ankle and the foot. The ankle is made up of six small cartilages called the **tarsals**, two of which form a transverse, proximal row, three a distal row, while one is in the center. The typical number of bones or cartilages in the vertebrate tarsus is ten, three being in the proximal and five in the distal row, while one or two are in the center. In the foot of Necturus four digits are present, each of which is composed of a proximal **metatarsal bone** and

two or three **phalanges** or toe joints. In the typical vertebrate foot five digits are present. The digit which is lacking in the foot of Necturus is the first.

Exercise 21. Draw an outline of the skeleton of the leg on a scale of 2 or 3, showing accurately the bones and cartilages.

The axial skeleton. The **skull** is made up of two regions, — the **cranium** and the **visceral skeleton.** The former incloses and protects the brain and the organs of special sense; the latter surrounds the mouth and pharynx, forming the framework of the jaws and the hyobranchial apparatus.

Both of these regions are composed entirely of cartilage in an early period of the animal's life, and certain portions remain cartilaginous, — this primitive cartilaginous skull being called the **chondrocranium.** As the young animal develops, however, certain parts of the cartilage are replaced by bone. Besides these **cartilage bones,** as they are called, other bones also make their appearance which develop, not in the cartilage, but in the skin and in connective-tissue membranes which cover the skull: these are called **membrane bones.** Thus, so far as the material of which it is made up is concerned, the skull is composed of cartilage, cartilage bones, and membrane bones.

Open the body cavity and remove the viscera. Strip off all the muscles from the skeleton. It is well to begin the process with the head, and to lay bare and study first the hyoid and gill arches which together form the hyobranchial apparatus, and then the lower jaw. These parts constitute the ventral portion of the skull and belong to the visceral skeleton. The skull must be kept in preserving fluid and not be allowed to get dry.

The **lower jaw,** or **mandible,** is a paired arch-shaped structure composed on each side of three bones and a cartilage. The bones are the following: the **dentary,** — a large bone which forms the anterior and nearly all of the outer surface of the mandible and bears most of the teeth; the **splenial,** — a small plate of bone on the inner surface of the mandible near its middle, which bears the hindermost teeth; and the **angular,** which is on the

inner surface of the mandible, extending from its hinder end forward about two thirds of its length. These bones are all membrane bones; they overlay the cartilage. This is Meckel's cartilage; it forms the axis of the mandible and is exposed to view on its inner side and at its hinder end, where it articulates with the upper part of the skull.

The **hyobranchial apparatus** is an extensive cartilaginous and bony structure which lies back of the mandible in the ventral body wall and supports the tongue and the gills. The whole structure is composed of four arches, all cartilaginous, the two foremost of which are complete, the right and left halves meeting in the median line, and lying parallel with the arch-shaped mandible, while the hindermost two are incomplete and lie parallel with the outer ends of the foremost arches. A slender median cartilage joins the two foremost arches, and a median rod of bone extends back from the second one.

The foremost of these arches is the **hyoid arch**: it supports the tongue. It consists of a right and a left half, each of which is made up of two bars of cartilage, — a short medial bar, the **hypohyal cartilage**, and a long lateral one, the **ceratohyal.**

The second arch is the **first branchial** or **gill arch**; each half is composed also of two bars of cartilage, — a long medial bar, the **ceratobranchial cartilage**, and the long lateral **epibranchial.** The third arch is the **second branchial arch.** It is incomplete, the two halves not meeting in the median line; each half is made up of a minute **ceratobranchial** and a long **epibranchial**, both of which lie back of and parallel with the first epibranchial cartilage. The fourth and last arch is the **third branchial arch**; it is also incomplete, consisting of a single **epibranchial** cartilage on each side which lies just back of the second epibranchial.

The two median pieces are the **first** and **second basibranchials**, the first being the median cartilaginous bar which joins the hyoid with the first branchial arch, and the second a slender median bone just posterior to the first branchial arch.

Exercise 22. Draw the mandible and the hyobranchial apparatus on a scale of 2.

Thoroughly clean the remainder of the skull and the anterior portion of the spinal column. Disarticulate the head from the spinal column.

Observe the flatness of the skull and its compactness. The cranial bones and cartilages are intimately joined with the remaining bones of the visceral skeleton, the whole forming so closely knit a structure that its various parts are not easy to separate from one another. At the hinder end is the **foramen magnum**, the large opening through which the spinal cord enters the brain cavity; at the forward end are two rows of small teeth. The cranial portion of the skull, which incloses and protects the brain and the special sense organs, forms the medial and larger part of it. The upper jaw and other portions of the visceral skeleton occupy the two lateral areas.

This part of the skull, like the lower jaw and the hyobranchial apparatus which have been already studied, is composed very largely of cartilage. Of the bones present the greater number are membrane bones, these being mostly thin plates which cover the cartilages and arch over the spaces between them. A few cartilage bones are present, however, in the hinder part of the skull.

The bones and cartilages of the cranium may be divided into two groups, — (*a*) those forming the cranium proper, or brain case, and (*b*) those forming the capsules of the special sense organs.

The **cranium proper** contains the following bones. Surrounding the foramen magnum, except a small space on the dorsal and ventral sides, are the paired **exoccipital bones**. They are cartilage bones; the remainder of the occipital region does not ossify but remains cartilaginous. Each exoccipital bears on its posterior surface an articular process — the **occipital condyle** — by which the skull articulates with the spinal column. Forming the roof of the cranium are two pairs of large membrane bones, the **parietals** and **frontals**. The parietals extend from the hinder end of the skull forward; the frontals overlap the anterior projections of the parietals and extend almost to the forward end of the skull.

The ventral portion of the cranium proper consists of a single very large membrane bone, — the **parasphenoid**, or **parabasal**, — which extends from the hinder almost to the forward end of the skull and forms the roof of the mouth.

Three pairs of **special sense capsules** are present, — the auditory, optic, and nasal.

The **nasal capsules** occupy the forward end of the skull. Each capsule is an elongated space which opens to the outside by means of the anterior and the posterior nares. The two anterior nares are situated at the forward end of the skull, with a wide space between them; the posterior nares are on the under surface, at the hinder end of the capsule, and open into the mouth. The nasal capsules consist largely of cartilage. The only bones which belong to them are a pair of large membrane bones, — the **vomers**, — which form most of their ventral surface. These bones overlap the forward end of the parasphenoid and bear teeth along their anterior edge; between them in the midventral area will be seen an internasal plate of cartilage. The roof and sides of the nasal capsules are formed by a delicate fenestrated cartilage which is covered above by the frontal bones.

The **optic capsules** are a pair of very delicate, ring-shaped cartilages, one of which surrounds the eyeball on each side, imbedded in its sclera; they cannot be seen in a dissection.

The **auditory capsules** are a pair of large, globular structures which lie at the hinder end of the skull, one on each side of the brain case. Each capsule consists largely of cartilage and is partly overlapped by the lateral edge of the parietal bone dorsally and by that of the parasphenoid bone ventrally.

Three cartilage bones are present in each capsule, — the opisthotic, the proötic, and the operculum. The **opisthotic** lies at the latero-posterior corner of the cranium and forms the hinder end of the skull at this place. The **proötic** lies directly in front of but not in contact with the opisthotic, and forms the forward end of the auditory capsule; it is at the level of the hinder end of the frontal bones. Within this bone is the membranous labyrinth of the ear. Both of these bones appear on both the

dorsal and the ventral side of the skull and are partly covered by the parasphenoid and the parietal bones. Between these two bones on the ventral side of the skull there appears a small round bone — the **operculum** — which exactly fits into a round opening in the auditory capsule called the **fenestra ovalis**; a short projection of this bone is directed forward and upward.

Along the entire outer edge of the auditory capsule is a flat membrane bone, called the **paraquadrate**, or **squamosal**, from the middle of which a short projection extends to the operculum.

The remaining bones of the skull belong to the visceral skeleton and may be divided into two groups, — the upper jaw and the suspensorium of the lower jaw.

The **upper jaw** is very weak in Necturus. In the typical amphibian it consists of two distinct arches, an outer or maxillary and an inner or palatopterygoid arch; in the frog the arches are well represented. In Necturus they are present only in part. The outer arch is represented only by the **premaxillary bones.** These are a pair of V-shaped membrane bones which form the anterior end of the skull and bear the anterior row of teeth. Maxillary and jugal bones — which in other amphibians lie back of these and complete the arch — are not present. The inner arch is represented only by the **palatopterygoid** bones, — a pair of large membrane bones which lie immediately back of the vomers and bear teeth at their forward ends.

The **suspensorium** is formed by the **quadrate cartilage**, the **quadrate bone** which develops in the cartilage, and the **squamosal** or **paraquadrate**, a membrane bone. The quadrate bone forms the extreme lateral portion of the skull; its anterior face is the surface with which the lower jaw articulates. The quadrate cartilage extends medially from the bone to the cranium. The paraquadrate, as we have already seen, lies along the side of the skull, extending from the quadrate bone back to the opisthotic.

Extending laterally from the cranium at the level of the forward end of the palatopterygoid bone, on each side, is a small cartilage called the **anteorbital** cartilage; it is very easily lost in the preparation of the skull.

Exercise 23. Draw the dorsal aspect of the skull on a scale of 2, showing accurately the outlines of the bones and cartilages. Indicate by shading the cartilages, cartilage bones, and membrane bones.

Exercise 24. Draw the ventral aspect in the same way.

Boil the skull until the bones can be separated from one another and from the chondrocranium. Carefully observe the extent of the latter and its relation to the cartilage and the membrane bones.

The **vertebral column** is composed of about forty-six vertebræ. Four regions may be distinguished in it, — a cervical region, consisting of the first vertebra, the atlas; a thoraco-lumbar region, consisting of about eighteen vertebræ; a sacral region, consisting of one vertebra, usually the nineteenth, which forms the sacrum and supports the pelvis; and a caudal region, consisting of the remaining vertebræ.

A typical vertebra is made up of the following parts: a cylindrical **centrum** or **body**; a flattened **neural arch** on the dorsal side of the centrum, in which the spinal cord lies; and a pair of large, irregular **transverse processes** at the sides of the centrum and neural arch which bear the ribs.

Note the shape of the centrum. It has a deep depression at each end, making it biconcave or amphicœlous, which is, in a fresh condition, filled with the soft notochord. The neural arch is made up of a pair of **neural processes**, — which form the lateral walls, — and the **neural spine**, which forms its roof. At each end of the neural arch is a pair of horizontally flattened prolongations called **zygapophyses**, by means of which the vertebræ articulate with one another.

Study the regions of the vertebral column. The first vertebra, which forms the **cervical region**, is called the **atlas**. It is about half as long as those immediately behind it, and has very short transverse processes. On its anterior surface is a pair of depressions into which the occipital condyles of the skull fit. The **thoraco-lumbar** vertebræ are the largest and all bear ribs. The **sacral** vertebra, which is usually the nineteenth, is similar to the

thoraco-lumbar in size and form; its transverse processes are, however, somewhat larger and its ribs longer than those of the other vertebræ, and the distal ends of the ribs articulate with the pelvic girdle. The **caudal** vertebræ vary much in form and size. The first two or three are similar to those of the thoraco-lumbar region, but are smaller, with transverse processes much less developed, and usually without ribs. From about the twenty-third vertebra a ventral or **hæmal arch**, in which the caudal vein and artery lie, characterizes the ventral side of the vertebra.

The **ribs** are small, rather irregular rods of bone, which are bifurcated at their proximal ends.

Exercise 25. Draw three views, on a scale of 2 or 3, of one of the thoraco-lumbar vertebræ and the ribs belonging to it, — an anterior view, a side view, and a ventral view.

Exercise 26. Draw the anterior end of the atlas on a scale of 2 or 3.

Exercise 27. Draw an anterior and also a side view of the twenty-fourth vertebra on a scale of 2 or 3.

AN ANURAN AMPHIBIAN. THE FROG

The Anura are the tailless Amphibia and include the frogs and toads. The following descriptions will enable the student to identify the commonest species of frogs.[1]

Rana virescens, the leopard frog. Green or brown, with large black blotches edged with white or yellow, which lie in two irregular rows on the back; legs barred above; belly pearly or yellowish; length about $2\frac{3}{4}$ inches; lives in marshes and wet places.

Rana palustris, the pickerel frog. Brown or greenish, with several rows of oblong square blotches on back and sides; length about 3 inches; common in cold springs or streams or in the grass.

Rana clamata, the green or spring frog. Green or brown, with rounded spots all over back; legs with several cross bands; beneath, pure white; length 3 inches; lives in ponds and streams.

Rana catesbiana, the bullfrog. Green or brown, with faint dark spots above; head often bright green; beneath, with pale blotches; length 5 to 8 inches; lives in ponds and streams.

Rana sylvatica, the wood frog. Pale reddish brown; head small and pointed with a dark band on each side between eye and arm; length $1\frac{1}{2}$ inches; lives in the woods and in the grass.

Three specimens will be needed for a complete dissection of the frog,—one for the outer form and the greater part of the internal organs, including the heart and the great blood vessels entering and leaving it; one for the blood vessels; and one for the skeleton. The animals should be killed as needed and preserved during the dissection in a five per cent solution of formalin.

Place the animal (alive if possible) under a glass or in a dissecting pan and observe its form and color. The body is short and compact, with a large head and mouth; the hinder end is characterized by the lack of a tail and by the great length of the hind legs. The color is such as to adapt it to the environment in which it lives, and may change from time to time, like that of a chameleon.

[1] These descriptions have been modified from *Bulletin No. 51* of the New York State Museum and Jordan's *Manual of Vertebrates*.

The skin of the frog is without scales or other hardened integumentary structures, such as are possessed by all vertebrates except the urodelan and anuran amphibians. It is, however, provided with numerous integumentary glands which secrete a protective slime. The characteristic triradiate openings of these glands may be seen with the aid of a hand lens in skin which the frog has shed; pieces of skin will often be found in the water in which the animals have been kept.

The body of the frog may be divided into two regions, — the **head** and the **trunk**. The neck region — which is wanting in fishes and is so characteristic of land vertebrates — is just beginning to make its appearance in amphibians. A distinct neck is not present; there is present, however, one cervical vertebra with which the skull articulates. The caudal region is also wanting in adult anurans. In the larval frog and toad a long tail is present, by means of which the animal swims; it is, however, gradually absorbed as the tadpole passes through its metamorphosis.

The head. This body division is triangular in shape. The **mouth** is large and bordered by skinny **lips**, which close tightly together like the cover on a box and thus prevent air from escaping during the act of respiration. The eyes are large and protruding. Each is protected by two **eyelids**, the upper one of which is large and thick and with little power of movement; the lower one is semitransparent and movable.

In front of the eyes are the **nostrils**, or **anterior nares** ; each of these is provided with a valve which can be tightly closed. The nostrils communicate directly with the mouth. Probe them with a bristle. Back of each eye is a large circular area, — the **tympanic membrane**, or ear drum, — which is thus on the outer surface of the body. Between the eyes is a small dark spot which marks the **frontal organ**: it is a rudiment of a median eye. In the male frog, in certain species, a pair of large **vocal sacs** projects from the hinder part of the head in the breeding season. Probe them from the mouth, if present.

The trunk. This body division is short and shows externally no marks of segmentation; it bears the appendages. In the middle of the back will be noticed a prominent hump, which

indicates the position of the sacrum, where the hinder appendages articulate with the spinal column. At the posterior end of the trunk and slightly dorsal in position is the small opening of the cloaca, the **anus**.

The appendages. Two pairs of **legs** are present: each leg is made up of three divisions, — a **proximal**, a **middle**, and a **distal division**, — which correspond to the upper arm, the forearm, and the wrist and hand respectively, in the fore leg, and in the hind leg to the thigh, the shank, and the ankle and foot. The toes have no claws.

The fore legs are relatively short and weak and do not aid in locomotion. Four fingers are present, the thumb being rudimentary. In the male frog the first finger is thickened. The fingers are not joined by a web.

The hind legs are long and muscular and are the principal organs of locomotion both on land and in the water. While the animal is at rest the hind legs are folded together back of it in a position ready for springing. In this position the three divisions of the leg become apparent. In the distal division certain ankle bones are much elongated and make this the longest of the three divisions. The five toes are webbed, — the medial (innermost) one being the big toe.

Exercise 1. Draw the animal as it sits or lies before you.

If the animal be still alive, it may be killed by placing it in a jar of water in which a small quantity of chloroform or ether has been put.

Exercise 2. Draw a dorsal view of the extended animal, showing the features above mentioned; carefully label all.

Exercise 3. Draw a side view of the head.

The mouth and pharynx. Open the mouth as wide as possible; cut each angle of the jaw a little, if necessary, so that the mouth will remain open. The mouth and pharynx will be seen to be a single space which extends back to the beginning of the œsophagus. With forceps pull the **tongue** forward; it is a

slimy, band like structure which is attached only at its forward end. The hinder end, which extends back into the pharynx, is bilobed. The lower jaw is without teeth. Just back of the tongue in the floor of the mouth may be felt the **hyoid cartilage**, which supports the tongue.

Back of the tongue is the **glottis**, — a median longitudinal slit which opens into the lungs. The glottis is in the middle of an elliptical elevation formed by the two **arytenoid cartilages**; it is usually closed, but may be opened with a needle. Place the end of a blowpipe in it and blow up the lungs.

The frog has two methods of respiration, — first with the skin and the mucous membrane of the mouth and pharynx, and second with the lungs. Air is taken by regular inspirations through the nostrils into the mouth and pharynx, where it is acted upon by the highly vascular mucous membrane. It is also at irregular intervals taken by an act of swallowing through the glottis into the lungs. It is expelled from the lungs by the elasticity of their walls — which contain muscle fibers — and that of the muscular sides of the body. Immediately after the expiration air is again swallowed, so that the lungs are kept filled. The floor of the mouth will be observed in the live frog to oscillate rapidly and regularly. This act is not connected directly with the pulmonary but rather with the pharyngeal respiration.

The opening behind the glottis into the digestive tract is the gullet, or **œsophagus**. Probe it.

In the roof of the mouth note the upper jaw, in which is a row of teeth called the **maxillary teeth**. Just behind them in the forward part of the mouth, near the median line, are two small groups of teeth called the **vomerine teeth**. On each side of these is one of the paired **posterior nares**, the inner openings of the nostrils. Probe them. Near the angle of the mouth on each side is the large opening into the tympanic cavity, the **Eustachian tube**. Probe one.

Exercise 4. Draw a sketch of the opened mouth and pharynx on a scale of about 2, and carefully label all the organs above mentioned.

The internal organs. Place the animal on its back in a dissecting pan containing water, with its head away from you, and pin it fast with a large pin through the tip of the jaw and one through each of the four legs. Raise the skin of the belly with forceps, and with scissors make an incision in it along the midventral line the entire length of the body.

Notice the looseness of the skin and the large space between it and the underlying muscles. This space is a lymph cavity. Note carefully the points where the skin is attached to the muscles. Note the large blood vessels on the inner surface of the skin: these are the cutaneous veins and arteries. The blood is brought to the skin to be aërated, an important part of the respiration of the animal being carried on through the skin.

Through the semitransparent muscles in the region of the fore legs may be seen and felt a number of platelike bones and cartilages. These form the pectoral (shoulder) girdle and the breastbone, which support the fore limbs. In the midventral line will be seen through the body wall a broad dark line: it is the abdominal vein.

Observe the arrangement of the ventral body muscles; see page 122.

Lift up the ventral body wall with forceps, and with scissors make a longitudinal incision through it in the median line the length of the body. Pull the two flaps of the body wall gently apart and pin them. Examine the organs which lie in the abdominal cavity, but without disturbing any of them.

If the animal be a male or a female which is not breeding, the most conspicuous organs will be the large reddish **liver** and the **intestine**. If it be a mature female, the dark-colored granular **ovaries** may occupy a large part of the space within the body cavity; in this case the ovaries should be removed so that the other organs can be studied.

Lying on the left side of the liver and wholly or partly concealed by it is the elongated **stomach**. In front of the liver in the median line is the conical **heart** within its membranous **pericardium**. Lying between the lobes of the liver may be seen the small greenish, spherical **gall bladder**.

Make a transverse incision in each flap of the body wall. Turn the flaps to the side and pin them down, exposing fully the internal organs.

In addition to the organs already mentioned one or both **lungs** may be seen. They are usually shriveled, saclike organs which lie at the forward end of the abdominal cavity, concealed by the liver. If either be full of air, it should be punctured and made to collapse. At the hinder end of the abdominal cavity, between the base of the hind legs, the large **urinary bladder** will be seen; if it is not found readily, insert the blowpipe in the anus and inflate the bladder. Several elongated yellowish bodies may be seen here projecting from between the other organs: they are called the **fat bodies**.

The **body cavity** is divided into two compartments, — the **abdominal cavity** and the **pericardial cavity**. The former is by far the larger of the two and contains the liver, intestine, and most of the other viscera; it is lined by a membrane called the **peritoneum**. The pericardial cavity is small, being only large enough to contain the heart and the base of the great blood vessels; it is formed by a membrane called the **pericardium**. Note that the organs in the abdominal cavity are attached to the walls or to each other by thin membranes. These are the **mesenteries**. They are folds of the peritoneum and have come into existence as a result of the growth of these organs in the body cavity. The peritoneum is a closed sac with extensive mesenterial folds extending into it, within which lie the various organs.

Exercise 5. Draw an enlarged outline of the animal and in it the internal organs as they lie in the body cavity before they have been disturbed; label all carefully.

The digestive system. This system consists of the mouth, pharynx, œsophagus, stomach, intestine, cloaca, liver, and pancreas.

The **mouth** and **pharynx** have already been studied. Without cutting anything, press the liver to the animal's right and fully expose the **stomach**. It will be seen to be a large, curved organ, the anterior or **cardiac** end being near the left lung at the side of

the heart, and the posterior or **pyloric end** being near the median line of the body. The **œsophagus** is a short tube, not quite as wide as the stomach, which joins the cardiac end of that organ with the pharynx.

From the pyloric end of the stomach, which is marked by a constriction, the **intestine** proceeds, with many turns, to the hinder part of the body. It is composed of two divisions, — the **small intestine**, and the **large intestine** or **rectum**. The small intestine forms the greater part of it. Its anterior portion — the **duodenum** — is bent forward so as to lie parallel with the stomach, and between them lies the whitish, irregularly shaped **pancreas**. The **rectum** is about half an inch long and forms the hinder part of the intestine; it is much wider than the small intestine and may often be recognized by its dark color. The rectum is continuous posteriorly with the **cloaca**, — a short, wide vessel which lies between the base of the hind legs and finds an outlet through the **anus**.

Observe again the extensive **mesenteries** which bind the divisions of the digestive tract with the wall of the abdominal cavity.

At one side of the forward portion of the rectum will be seen a dark-red spherical body, — the **spleen**. Press the intestine and mesentery aside, — but without cutting them, — and observe the flattened, dark-colored **kidneys**, which lie close to the dorsal body wall. At their forward ends are the two yellow, spherical **testes**, — if the animal be a male, — or the irregular, saclike **ovaries** if a female, while in front of these organs are the yellow, finger-shaped **fat bodies**.

Observe closely the **liver** and **pancreas**. The former is composed of two main lobes, one of which is subdivided into two smaller lobes. Note carefully the connection between these two parts. Turn the whole liver forward, — but without cutting anything, — pin it there, and study its dorsal surface and the pancreas.

The **pancreas** is an irregular, whitish gland which lies in the bend made by the stomach and the duodenum. Near the hinder border of the liver note the spherical **gall bladder**. Find the **bile**

duct, which joins the liver with the duodenum. It is a slender tube which issues from the gall bladder and, after receiving a number of branch ducts from the liver, joins the duodenum a short distance from the pylorus. It passes through the pancreas, from which it receives one or more small **pancreatic ducts**. Gently squeeze the gall bladder with forceps and force the dark-green bile into the duct; it will thus be easy to follow. If the bile will not flow, cut the gall bladder open and inject a carmine solution in it with a pipette.

Exercise 6. Make a semidiagrammatic drawing of the dorsal surface of the liver and pancreas, with an outline of the stomach and duodenum, showing the features just described; carefully label all the organs.

The study of the digestive system will be completed after the heart has been examined.

The heart and its vessels. The **heart** of the frog is composed of five divisions, — a single ventricle, two auricles, the sinus venosus, and the truncus arteriosus. Observe the pericardium, which closely invests the heart.

The **ventricle** is the large conical posterior portion of the heart; by its contractions the blood is sent forward through the **truncus arteriosus**, which is the large cylindrical vessel springing from its anterior end. The truncus is made up of two portions, — a basal portion, which is called the bulbus cordis, and an anterior portion. The latter at once divides into two large vessels which pass forward and leave the pericardial space. Each of these vessels then divides into three arteries, called the **aortic arches**, through which the blood is carried to all parts of the body. The anterior arch is called the **carotid arch**; it carries blood to the head. The middle arch is called the **systemic arch**. The right and left sides of this arch meet back of the heart and form the **aorta descendens**, or **dorsal aorta**, which lies just beneath the spinal column and distributes arterial blood to the trunk and extremities. The posterior arch is the **pulmocutaneous arch**; through it blood is carried to the lungs and the skin for aëration.

In front of the ventricle are the **right** and **left auricles**; they appear dark colored in consequence of the thinness of their walls. On the dorsal side of the heart is a large, thin-walled, dark-colored sac, — the **sinus venosus.** Blood is brought to the heart from the organs and tissues of the body by three large veins which enter the sinus venosus: these are the **right** and **left precaval veins,** which enter the forward end of the sinus, bringing blood from the forward part of the body; and the **postcaval vein,** which enters the hinder end of the sinus, bringing blood from the hinder part of the body. From the sinus the blood enters the right auricle. Blood is brought to the heart from the lungs by the **pulmonary vein,** which lies alongside the left precaval vein and enters the left auricle; this vein is formed by the union of a right and a left pulmonary vein which bring blood from the two lungs.

Exercise 7. Make a drawing of the ventral aspect of the heart and the blood vessels, so far as these have been observed, on a scale of 2 or 3.

Bend the ventricle forward and study its dorsal aspect. Identify the sinus venosus, the three caval and the pulmonary veins.

Exercise 8. Make a drawing of the dorsal aspect of the heart on a scale of 2 or 3.

The internal structure of the heart. Cut the aortic arches and the caval veins and remove the heart from the body. Place it in a small dish of water with the dorsal side uppermost, Identify the stumps of the three caval veins and the pulmonary vein. Cut off the dorsal wall of the sinus venosus and wash the blood from its cavity. Note the opening into the right auricle; if it is not easily seen, use the blowpipe.

Place the ventral surface of the heart uppermost; cut away the ventral wall of the two auricles and wash the blood from their cavities. Note the thin septum which separates the right from the left auricle.

In the right auricle, which is the larger of the two, note the opening into the sinus venosus, near the septum; also note the muscular ridges on its inner surface. In the left auricle note the small opening of the pulmonary vein, also near the septum, and the muscular ridges.

Remove the ventral wall of the ventricle and expose its cavity. Note the smallness of its cavity, its thick walls, and the longitudinal muscular ridges on its inner surface which divide the cavity into compartments.

The presence of these elongated compartments is important inasmuch as they prevent the complete mixing of the venous and the arterial blood which would otherwise take place. Since the ventricle consists of a single chamber into which both kinds of blood are poured from the auricles, it would contain an equal mixture of these if the blood could flow unimpeded from one part of the ventricle to another. As it is, venous blood from the right auricle goes into the compartments on the right side of the ventricle, and the more nearly arterial blood from the left auricle goes into those on the left side, and but a slight mixing of the blood probably takes place.

At the forward end of the ventricle is the **auriculo-ventricular opening,** which leads into the ventricle from both auricles. The septum between the auricles divides this opening into two passages, one of which leads from each auricle. This opening is guarded by a **semilunar valve** extending into the ventricle, to the dorsal wall of which it is attached by tendinous cords. Look for them with the aid of the blowpipe.

At the forward end of the ventricle, also, to the right, is the opening into the truncus arteriosus. It is guarded by three **semilunar valves.** Look for them with the aid of the blowpipe.

The space in the truncus is incompletely divided into two compartments by a large longitudinal ridge springing from its dorsal wall which is called the **spiral valve.** Of these compartments the right-hand one may be called the arterial compartment, and the left-hand one the pulmocutaneous compartment. Note carefully the shape of the spiral valve and its relation to the opening into the ventricle.

At the forward end of the spiral valve are three additional pouch-shaped valves. The one of these on the right side is the anterior end of the spiral valve; it is the largest of the three. The other two are one on the left and one on the dorsal side of the truncus and are much smaller. These things are difficult to see except in a large frog.

Make a cross section of one of the two branches of the truncus and note that it is divided by longitudinal partitions into three chambers which communicate with the three aortic arches. Probe these chambers. The innermost or anterior chamber takes blood to the carotid artery, the middle chamber takes it to the systemic artery, and the outer or posterior chamber takes it to the pulmocutaneous artery. Note that the pulmocutaneous chambers on the two sides meet and open posteriorly through a single aperture at the anterior end of the pulmocutaneous compartment of the truncus, which has received venous blood from the ventricle. The arterial compartment which has received arterial blood delivers it to the carotid and systemic arches.

It will be seen that the purpose of this arrangement is to effect such a division of the blood that the pulmocutaneous arch will receive principally venous blood, which it takes to the lungs and the skin to be purified, while the more nearly arterial blood comes into the carotid and systemic arches and is distributed throughout the body.

Exercise 9. Draw a diagrammatic sketch of the heart with the ventral wall removed, showing these features.

The digestive system (*continued*). Take out this system in the following way. Lift up the liver with forceps, and with scissors free its anterior border from the tissues beneath it, being careful not to injure the lungs. Find the œsophagus, which joins the stomach with the pharynx. Note that the lungs also join the ventral wall of the pharynx. Take hold of the œsophagus with forceps, lift it up, and with scissors cut across the floor of the mouth in front of the lungs.

The forward end of the digestive tract, with the lungs, being thus cut loose from the body, can be bent backward. With scissors cut the stomach and liver loose from the tissues beneath them; cut the mesentery by which the intestine is joined with the dorsal body wall, being careful not to injure the flattened kidneys and testes or ovaries, and straighten the intestine out. The entire digestive tract, together with the lungs, will thus be removed from the body, except at its hinder end. Extend it in the water and pin it there, with the lungs attached to the pharynx, and the liver and pancreas attached to the duodenum by the bile duct.

Exercise 10. Make a drawing of the digestive system, with the lungs; label all the parts and organs belonging to it.

Slit open the stomach and the forward end of the intestine and note the ridges on their inner surface. Cut open a lung and note that it is a hollow sac with a network of ridges on the inner surface.

The urogenital system. The urinary and the genital organs are in close union with each other, notwithstanding their difference in function, and are conveniently studied together. The **urinary organs** consist of the paired kidneys, the paired excurrent canals or Wolffian ducts, the urinary bladder, and the cloaca.

The **kidneys** are two large, flattened bodies which lie close to the dorsal body wall in the posterior portion of the body cavity. Each kidney is made up of a mass of fine tubules, each of which opens into the body cavity at one end, while the other end communicates with the **Wolffian duct.** This duct acts as a ureter. It is a straight white tube which runs from the outer border of the kidney to the dorsal wall of the cloaca. The **urinary bladder** is a large, bilobed sac at the hinder end of the body cavity which springs from the ventral wall of the cloaca. Its opening into the cloaca can be applied closely to the openings of the Wolffian ducts and it can thus receive the urine from them.

On the ventral surface of each kidney is an irregular, yellowish line which is called the **adrenal body**; its function is unknown.

Examine the ventral surface of the kidney with a hand lens and note the minute openings of the urinary tubules.

The **genital organs** consist of the testes in the male and the ovaries in the female, and the ducts which conduct the genital products to the outside.

The male. The **testes** are two yellow, ovoid bodies which lie against the ventral surface of the kidneys and are attached to the dorsal wall of the abdominal cavity by mesenteries. Joining each testis with the ventral side of the kidney are about a dozen fine tubules, the **vasa efferentia**, which are suspended in the mesentery. Through these the spermatozoa, which are formed in the testis, make their way into the kidney and thence into the Wolffian duct. This duct thus serves the double function of a ureter, an outlet for the urine, and a vas deferens, an outlet for sperm; it has on this account received a special name and is called **Leydig's duct**. It is only in elasmobranchs and amphibians that Leydig's duct is present. Along the hinder end of this duct and connected with it by ducts is the **seminal vesicle**, — a glandular body in which sperm is stored during the breeding season.

The female. The **ovaries** differ very much in size and appearance at different times of the year. In the springtime they are often so distended with the small, spherical ova that they may almost fill the abdominal cavity. If this is not their condition, they appear as a pair of folded, dark-colored bodies which lie on the ventral surface of the kidneys attached to the dorsal body wall by median mesenteries. The paired ducts through which the ova find their way to the cloaca are the **oviducts**, or **Müllerian ducts**. In adult females each of these ducts is a thick-walled, twisted tube which lies in the abdominal cavity against the dorsal body wall. Its anterior end opens into this cavity and is situated at the side of the heart, while the posterior end opens into the cloaca. The posterior portion of the oviduct is expanded and forms a **uterus**, a reservoir for ova.

The ova escape from the ovaries by the rupture of their walls into the abdominal cavity; they then make their way to the mouths of the oviducts and through them into the cloaca.

During this descent of the ova the albumen which surrounds it is secreted by the walls of the oviducts.

At the anterior end of the kidneys is a pair of prominent, yellow, branching **fat bodies**. They are lymphoid bodies, and vary much in size at different times of the year, being largest before the breeding season and smallest after it.

While studying the urogenital system, the organs of which it is composed need not be disturbed. With a strong scalpel cut through the bony pelvis exactly in the median line between the legs in order to expose the cloaca. The urinary bladder is a delicate structure which is attached to the body wall by mesenteries. It must be freed from these and great care taken not to cut either it or the cloaca.

Slit open the cloaca along the side and find the mouth of the urinary bladder. Search with the blowpipe for the openings of the urogenital ducts.

Exercise 11. Make a semidiagrammatic drawing of the urogenital system with the cloaca; label carefully all its parts.

The nervous system. This system is made up of the following divisions: (1) the **central nervous system**, which is composed of the brain and the spinal cord; (2) the **peripheral nervous system**, which is composed of (*a*) the paired cranial and spinal nerves and (*b*) the sympathetic nervous system; and (3) the **special sense organs.**

The cranial nervès and the spinal nerves each number ten pairs; the former spring from the brain and the latter from the spinal cord and place these structures in communication with the various organs and tissues of the body. The sympathetic nervous system lies in the body cavity in connection with the cranial and spinal nerves and innervates certain important viscera.

Remove the urogenital system from the body. Raise it carefully with forceps, and with fine scissors cut it loose from the dorsal body wall. Note the spinal column projecting into the body cavity, and lying ventral to it note a large blood vessel, —

the dorsal aorta; this must not be disturbed. The spinal column is made up of nine vertebræ and a long terminal bone called the **urostyle.** Identify them.

We shall study first the **spinal nerves** and the **sympathetic system.** Each spinal nerve is joined with the spinal cord by two roots, — a dorsal and a ventral root, — and passes out from the neural canal of the spinal column through a space between two vertebræ called the **intervertebral foramen.** At the point where these two roots meet, the dorsal root bears a large ganglion called the **spinal ganglion.** This ganglion is imbedded in a prominent white body present between the vertebræ called the **calcareous body.**

The ten pairs of spinal nerves will be seen in the body cavity, where they appear as white strands which lie against the dorsal body wall on each side of the vertebral column. The most conspicuous ones are the seventh, eighth, and ninth nerves, which lie close together in the hinder part of the abdominal cavity. They emerge on each side from the intervertebral foramina, between the seventh and eighth vertebræ, the eighth and ninth, and the ninth and the urostyle respectively, and proceed straight back almost parallel with the spinal column. These nerves are joined with one another by short connecting branches and form a network or plexus called the **sciatic plexus.** From this plexus issue a number of nerves which proceed to the hinder quarters of the body and the hind legs. Of these the largest are the **sciatic nerve,** which goes to the hind leg, and the **crural** and **iliohypogastric nerves,** which supply the muscles and skin of the abdomen and thigh.

Find the sciatic plexus and these nerves. Follow the sciatic nerve into the leg; trace the other two as far as possible.

In the forward part of the abdominal cavity, on each side, is another nerve plexus called the **brachial plexus,** which is composed of the first three spinal nerves. Of these the second, which is the largest and most conspicuous, is a large white cord lying at right angles to the spinal column and emerging from between the second and third vertebræ; it is joined by a small branch from the first and one from the third spinal nerves, and passes to the fore leg.

The fourth, fifth, and sixth pairs of spinal nerves are delicate cords which emerge from between the fourth and fifth, fifth and sixth, and sixth and seventh vertebræ, and pass obliquely backward to the muscles of the back.

Find these nerves and trace their branches.

The **sympathetic system** consists of a pair of delicate **longitudinal nerves** which lie in the abdominal cavity on either side of the spinal column, close to the dorsal body wall. In each longitudinal nerve are ten enlargements,—the **sympathetic ganglia,**—from each of which one or more short branches run to a spinal nerve.

The first, second, and third of these ganglia lie close to the first, second, and third spinal nerves and are joined with them by short branches. The fourth to the ninth sympathetic ganglia, inclusive, are situated nearer the median plane than the first three; they, together with the longitudinal nerve, lie alongside the dorsal aorta, which will be noticed as a median, dark-colored tube. The fourth sympathetic ganglion is the smallest; the ninth is the largest and is joined with the ninth spinal nerve by several branches; the tenth is small and is often wanting.

Branches from the sympathetic nerves and their ganglia pass to the various viscera. The largest of these branches proceed from the fourth, fifth, and sixth ganglia, and after joining together form a large nerve called the **splanchnic nerve**, which supplies the intestine and other viscera.

Study the sympathetic system; first find the longitudinal nerves and ganglia, then observe their relations to the spinal nerves and ganglia.

Exercise 12. Make a semidiagrammatic drawing of the spinal nerves and the sympathetic system. Draw first an outline of the spinal column as it appears in the ventral aspect of the opened body cavity; number the vertebræ; draw the spinal nerves and then the sympathetic system.

The brain and the spinal cord. In order to expose these organs remove the skin and muscles from the back of the head and trunk. Find the juncture of the skull with the backbone. By

bending the head slightly down, a space about an eighth of an inch long, which is covered by a dark-colored membrane, may be made to appear between the skull and the backbone. With a needle very carefully remove this membrane; beneath will be seen the white brain; this must not be injured. Introduce one blade of the scissors into the skull through the opening, and make a cut along the side of the skull between the eyes. Make a similar cut along the other side, and with the forceps lift off the roof of the skull, thus exposing the brain. Similarly cut through the two sides of the neural canal, which contains the spinal cord, and expose it.

Carefully remove the dark membrane which covers the brain, and observe its five regions,—the cerebrum, the thalamencephalon, the optic lobes or midbrain, the cerebellum, and the medulla oblongata.

The brain and spinal cord are hollow structures. A delicate canal, called the **central canal**, runs through the center of the cord; in the brain this canal widens out into a number of spaces which are called the **ventricles**.

The anterior and largest region of the brain is the **cerebrum**. It is made up of the two lateral **hemispheres**, which are separated from each other by the **sagittal fissure**. The anterior ends of the hemispheres are fused and form the **olfactory lobe**, from the anterior end of which the two **olfactory nerves** pass to the nose.

Back of the cerebrum is the inconspicuous **thalamencephalon**, and behind that are the paired **optic lobes**, or **midbrain**. In the roof of the thalamencephalon will be seen, with the aid of the lens, several delicate structures. Near the center of it arises a threadlike projection called the **pineal body**, or **epiphysis**, which extends forward over the thalamencephalon. In an early period of the larval life of the frog the epiphysis extends through the skull to the skin on the top of the head between the eyes, where it joins the brown spot known as the frontal organ, which is the rudiment of the pineal eye; this connection is lost before the animal becomes adult.

In front of the epiphysis and between the hinder ends of the hemispheres is the much larger **paraphysis**, a dark-colored, vascular

body extending up to the skull. At its base and partly concealed by it is the **anterior choroid plexus**, the roof of the thalamencephalon.

Back of the optic lobes and separated from them by a deep groove is a narrow, transverse ridge, the **cerebellum**, and back of that is the **medulla oblongata**, which is continuous with the spinal cord. The dorsal wall of the medulla is a dark-colored, vascular membrane called the **posterior choroid plexus**, beneath which is the **fourth ventricle** of the brain. The triangular depressed area which these structures form is called the **fossa rhomboidalis.**

The **spinal cord** is the portion of the central nervous system which lies in the neural canal of the spinal column. It is a thick, white band, oval in cross section, from which the paired spinal nerves spring. At two points it is swollen,—where the spinal nerves which form the brachial plexus, and where those forming the sciatic plexus, respectively, leave it. The hinder end of the cord tapers rapidly until it becomes a fine thread which extends into the urostyle.

Exercise 13. Draw the dorsal aspect of the brain and the spinal cord.

Study the **lateral surface** of the brain and the proximal portions of the **cranial nerves.** Ten pairs of these nerves are present in the frog; several pairs are so small, however, that they may not be seen.

The first cranial nerve is the **olfactory**, which extends forward from the olfactory lobe. Cut away the roof of the anterior portion of the skull and follow the two olfactory nerves forward. Each will be seen to branch a short distance in front of the olfactory lobe and be distributed to the walls of the nasal capsule.

Cut the olfactory nerves. Dissect away the left side of the skull and expose the left surface of the brain, preserving so far as possible the nerves which will be seen coming from it.

Lying close to the inner wall of the skull, at the hinder end of the orbit, is a yellowish body, often surrounded by a calcareous sac. This is the **Gasserian ganglion**, and must not be

injured. Just behind the hemispheres the **optic nerve**, the second cranial nerve, issues from the ventral surface of the thalamencephalon and extends forward to the eye. The thickened side of the thalamencephalon is called the **optic thalamus.**

The third and fourth cranial nerves — the **oculomotor** and the **trochlear** — are very small and will hardly be found; they go to muscles of the eyeball. The oculomotor springs from the ventral surface of the midbrain, the trochlear from the dorsal surface between the optic lobes and the cerebellum.

The fifth, sixth, seventh, and eighth cranial nerves — which are the **trigeminal, abducens, facial,** and **auditory**, respectively — arise close together from the forward end of the medulla oblongata. The first three of these nerves, together with the anterior end of the sympathetic nerve, are united in the Gasserian ganglion. The trigeminal nerve is the largest of these three; it arises from the side of the brain just beneath the cerebellum and passes forward to the ganglion. The abducens is a very slender nerve which arises from the ventral surface of the medulla near the median line. The facial and auditory nerves arise close together behind the trigeminus. The latter is the larger and passes directly to the auditory capsule; the former is much smaller and passes alongside the trigeminus to the Gasserian ganglion.

This ganglion, it will be seen, is not strictly homologous to the same ganglion of higher vertebrates, in which it belongs exclusively to the trigeminal nerve. On this account it is sometimes given another name in the frog, and is called the **proötic ganglion.**

Four nerves leave the Gasserian ganglion and at once pass through a large foramen in the skull into the hinder part of the orbit. Pull the eyeball gently forward, cut its muscles and the optic nerve, and remove it. Two of these nerves — the **ophthalmic** and the **maxillo-mandibular** — belong to the trigeminal and two — the **palatine** and the **hyomandibular** — belong to the facial nerve. The abducens becomes a part of the ophthalmic.

The **ophthalmic** is a prominent nerve which passes straight forward along the upper portion of the orbit to a foramen at its

forward end, where it leaves the orbit; it then passes into the nasal capsule and divides into two branches. Near its base this nerve gives off two small branches which represent the abducens nerve and go to the muscles of the eyeball. The **maxillo-mandibular** passes laterally from the ganglion and almost immediately divides into two nerves, — the maxillary and the mandibular, the former of which passes along the mediocentral wall of the orbit to the upper jaw, the latter along the latero-dorsal wall of the orbit to the lower jaw.

The **palatine** is the hindermost of the nerves leaving the Gasserian ganglion. It runs along the ventral wall of the orbit and innervates the mucous membrane of the mouth, with which it lies in contact. The **hyomandibular** runs laterally from the ganglion to the angle of the mouth.

The ninth and tenth cranial nerves—the **glossopharyngeal** and the **vagus** or **pneumogastric**, respectively — arise from the side of the medulla, back of the auditory nerve, by four roots. These uniting form a single nerve, which emerges from the cranial cavity by a foramen at the side of the foramen magnum. Immediately back of this foramen it expands into the large **jugal ganglion**, from which the glossopharyngeal and the vagus proceed. The former passes forward to the tongue; the latter passes backward along the pharyngeal wall, giving off branches which supply the muscles of the shoulder, the larynx, heart, lungs, and stomach.

Exercise 14. Draw the lateral aspect of the brain on a scale of 3, and the cranial nerves so far as observed.

Study the **ventral surface** of the brain. Cut the cranial nerves and remove the brain from the skull. Put it in a dish of water and study its ventral surface. Identify the olfactory lobe, the hemispheres, and the structures belonging to the thalamencephalon. The optic nerves will be seen issuing from the **optic chiasma**,—a structure formed by the crossing of the optic nerves on the ventral side of the brain. Behind the optic chiasma is the **infundibulum**, a large median projection which is divided into a right and a left lobe, and extending from the hinder end of

which is a flattened body called the **pituitary body,** or **hypophysis.** This body is lodged in a depression in the floor of the cranial cavity, and usually remains there after the brain is removed from the skull.

The ventral portion of the midbrain is formed by the **crura cerebri,** which lie beneath the optic lobes and are partly concealed by the infundibulum. Arising from the crura near the middle line may be seen the very delicate oculomotor nerves.

The medulla oblongata is but slightly wider than the spinal cord. A longitudinal groove is present in the midventral line of both.

Exercise 15. Draw the ventral aspect of the brain on a scale of 3.

The ventricles of the brain. With a sharp scalpel remove the dorsal wall of the brain and expose the cavities within. Each hemisphere has a large cavity; these are called the **first** and **second** or **lateral ventricles.** A median canal called the **foramen of Munro** joins them with each other and with the **third ventricle** which is a narrow median space situated in the thalamencephalon. Extending back from the third ventricle through the midbrain is a median canal called the **aqueductus Sylvii**; the large cavity in each optic lobe is joined with it. The **fourth ventricle** is in the medulla; it is a triangular space which at its hinder end is continuous with the central canal of the spinal cord.

Exercise 16. Draw a diagram showing these structures.

The vascular system. This system is made up of the following parts: (1) the **heart,** a muscular pump which is continually driving the blood to all parts of the body; (2) the **arteries,** the vessels through which the blood is carried away from the heart; (3) the **veins,** the vessels through which the blood is returned to the heart; (4) the **capillaries,** the minute vessels which connect the veins and arteries.

Kill a frog and pin it down as directed on page 96. Make a midventral incision through the skin from the tip of the snout to the anus. Note the prominent cutaneous veins on the inner surface of the skin. Identify first the abdominal vein through the

ventral wall of the abdomen. This vein lies in the body cavity against the ventral abdominal wall and will appear as a dark median line. Open the body cavity by a longitudinal incision to one side of the midventral line, in order to avoid cutting the abdominal vein, from the anus to the tip of the lower jaw. Take great care not to cut the blood vessels or other organs within.

Dissect the abdominal vein free from the body wall, or — if this is difficult on account of the small size of the frog — slit the body wall on each side of the vein, leaving it attached to a narrow strip. Free the attachments of the liver to the body wall, spread the two flaps to the right and left, making a short transverse cut in each, and pin them fast, exposing fully the heart, liver, and other internal organs. If the animal be a female the ovaries should be removed if they obscure the other organs.

The heart and the blood vessels leaving and entering it have already been studied (page 101).

The veins.[1] The veins may be divided into two groups, which are (1) the **systemic veins**, those which enter the sinus venosus, with their branches, bringing, for the most part, venous blood from the various organs and tissues; and (2) the **pulmonary veins**, which enter the left auricle, bringing arterial blood from the lungs.

We shall first study the systemic veins. These may be subdivided into two groups: (*a*) the **caval veins**, which bring blood directly to the heart; and (*b*) the **portal veins**, which bring blood directly to the liver and kidneys, whence it goes to the heart.

Three large caval veins are present, which enter the sinus venosus; two of these — the **right** and **left precavals** — bring blood from the anterior half of the body, including the fore legs; the other — the **postcaval** — brings blood from the posterior half of the

[1] The veins are usually easily studied without being injected, as they are colored by the blood in them. The animals should not be dissected fresh, but the blood should be permitted to harden in the veins first. If it is wished to inject them, this should be done through the abdominal vein in both directions for the portal systems, and through the postcaval vein for the remaining systemic veins. The arteries can be much better studied if they are injected; this should be done through the ventricle and truncus arteriosus.

body. The blood brought by the postcaval veins is venous blood, but with that brought by the precavals a certain quantity of arterial blood has mingled. The prominent cutaneous veins which we have already observed on the inner surface of the skin belong to the precaval system, and as the blood in them has been purified by contact with the air through the skin and the mucous membrane of the mouth and pharynx, that poured by the precavals into the heart is a mixed blood.

Turn the apex of the heart forward and observe the two large precaval veins which enter the sinus venosus at its forward end. Each precaval is formed by the union of three veins, which meet immediately in front of the heart. These are the **external jugular**, the most anterior of the three, which brings blood from the head; the **innominate vein**, the middle one, which brings blood from the brain, the shoulder, and the forearm; and the **subclavian vein**, the largest and hindermost, which brings blood from the arm and the skin.

Without cutting any more than is absolutely necessary, trace the external jugular forward. Near the hinder margin of the head it is formed by the union of two veins, — the **lingual** and the **internal mandibular veins**; the former arises in the tongue; the latter lies along the inner margin of the lower jaw.

The **innominate vein** is formed by the union of two veins, — the **internal jugular**, which brings blood from the head, and the **subscapular**, which is one of the two veins returning blood from the fore leg.

Several small glandular bodies are present near the external and internal jugular veins, of which the **pseudothyroid**, the **thyroid**, and the **thymus glands** are the most important. The first of these, which is often wrongly called the thyroid, is a small ovoid body which lies next to the inner ventral surface of the external jugular. It arises during the metamorphosis of the animal as a thickening on the walls of the branchial clefts. The **thyroid gland** is a somewhat larger body near the pseudothyroid but dorsal to it. The **thymus** is a small ovoid body just back of the hinder margin of the tympanic membrane near the internal jugular vein.

The **subclavian vein** is formed by the union of two veins, the **brachial vein**, which is one of the two veins returning blood from the fore leg, and the **great cutaneous vein**, which returns it from the skin. Follow the former vein and its branches. The latter vein occupies a peculiar position in that it is partly respiratory in function. It lies on the inner surface of the skin, receiving numerous branches, and may be traced forward into the head, where it receives branches from the mucous membrane of the mouth and the pharynx. It is, however, not wholly respiratory, as it also receives branches from muscles.

Exercise 17. Draw a diagrammatic sketch showing the precaval veins and their branches so far as observed.

The **postcaval** is a large median vein which enters the posterior end of the sinus venosus. It arises between the kidneys and runs along the middorsal wall of the abdominal cavity, just beneath the dorsal aorta, to the liver, through which it goes to the heart. Press the intestine to one side, but without cutting anything, and observe it and its branches.

The postcaval vein receives the following branches: the **renal veins**, five or six pairs in number, from the kidneys; the **spermatic veins** (in the male) or **ovarian veins** (in the female), from two to four pairs in number, which join the postcaval between the renal veins, bringing blood from the genital organs; the **adipose veins**, a pair of veins from the fat bodies; the **hepatic veins**, three in number, from the liver.

Exercise 18. Draw a diagrammatic sketch showing the postcaval vein and its branches so far as observed.

The portal system of veins. A portal vein is one which does not go directly to the heart but either to the liver or the kidneys, where it divides up into capillaries and distributes the venous blood throughout these organs. In the frog two portal systems are present, — the **hepatic portal**, by which blood is taken to the liver, and the **renal portal**, by which it is taken to the kidneys.

The hepatic portal system. This system is made up of two large veins and their branches,— the **abdominal vein**, which brings blood from the hind legs, and the **hepatic portal vein**, which brings it from the digestive tract and the spleen.

The **abdominal vein** is a median ventral vein which has already been seen. It is formed by the union of the **right** and **left pelvic veins**, which come from the hind legs. Trace the abdominal vein back and find them. Note the branches the abdominal vein receives from the gall bladder, the heart, the urinary bladder, and those from the body wall. Cut the abdominal vein in the middle; turn the liver forward and expose its dorsal surface; fasten it with pins in this position.

Trace the abdominal vein forward to the liver. Just to the left of the gall bladder it divides into three branches, two of which go to the right and left lobes of the liver, while the third joins the hepatic portal vein.

Study the **hepatic portal** and its branches. It is a short, wide vein which lies in the mesentery and enters the left lobe of the liver. Near the point where it enters the liver it is joined by the branch of the abdominal vein just mentioned. The hepatic portal receives numerous branches, called the **intestinal veins**, which lie in the mesentery and come to it from the small and large intestines. It also receives the **splenic vein** from the spleen, the two large **gastric veins** from the stomach, a **gastroduodenal vein** from the stomach and duodenum, and a number of small **pancreatic veins** from the pancreas. The anterior portion of its course is through the pancreas.

Exercise 19. Draw a semidiagrammatic sketch showing the hepatic portal system; also outlines of the organs with which it enters into relations.

The renal portal system. This system is made up of veins from the hind legs, the dorsal body wall, the kidneys, and, in the female, the oviducts; it is joined with the abdominal vein by the pelvic veins, which have just been observed, and with the kidneys by the renal portal veins.

Two veins — the **femoral** and the **sciatic** — collect the blood of the hind leg on each side of the body. The femoral is the larger of these. It is a large vein which appears on the ventral surface of the leg, where it divides into two branches. The larger of these is the **pelvic vein**, just mentioned, the other is the **external iliac.**

The sciatic vein lies on the back of the thigh. It passes forward and joins the external iliac. The vein so formed is the **renal portal**, which runs forward to the outer margin of the kidney at its hinder end. The vein then continues within the kidney close to its lateral margin, and gives off numerous branches, which break up into capillaries in the kidney. At about the middle of the kidney a vein comes from the side and joins the renal portal. This is the **dorsolumbar vein**; it collects blood from the dorsal body wall. In the female a large number of veins from the oviduct also enter the lateral margin of the kidney and join the renal portal vein.

Trace the abdominal vein back and find the pelvic veins. Follow one of the pelvic veins back to the base of the leg, where it will be seen to be one of the two branches into which the prominent femoral vein divides. Trace the other branch, the external iliac, forward to its point of union with the sciatic vein; trace the renal portal vein to the kidney. Study the distribution of the femoral and sciatic veins in the leg. Observe the dorsolumbar vein entering the kidney in the middle of its lateral margin and study its distribution. Observe the oviducal veins, if the animal be a female.

Exercise 20. Draw a semidiagrammatic sketch showing the renal portal system, together with an outline of the organs with which the veins enter into relations.

The pulmonary veins. The **common pulmonary** enters the left auricle. It is a very short vein and is formed by the union of the **right and left pulmonaries**, which come from the right and left lungs respectively. Each pulmonary vein lies along the medial side of the lung, the right pulmonary being somewhat longer than the left. Turn the apex of the heart forward and find these veins.

Exercise 21. Draw a diagram of the entire venous system.

The arteries.[1] All the blood in the heart leaves it through the truncus arteriosus, the structure of which has already been observed. At its anterior end the truncus divides into a right and a left branch, each of which after passing through the pericardium again divides into three branches, — the **carotid, systemic,** and **pulmocutaneous aortic arches.** The last named of these arches, which is the hindermost in position, branches off from the others a short distance in front of the pericardium; the other two usually remain together a short distance before separating.

The anterior aortic arch — the **carotid** — passes forward and dorsally a short distance and then divides into two vessels, — the **internal** and the **external carotid arteries.** At this point the walls of the arteries are thickened and spongy, and the ovoid structure thus formed is called the **carotid gland**; it is not a gland, however, but probably acts as an accessory heart. The internal carotid, the larger of the two, goes dorsally and then forward and supplies the brain, the orbit, and the mucous membrane of the roof of the mouth. The external carotid passes directly forward and supplies the tongue and the muscles of the lower jaw.

The posterior aortic arch — the **pulmocutaneous** — takes blood to the lungs and skin to be oxygenated. On each side just back of the carotid gland it divides into two arteries, — the **pulmonary** and the **great cutaneous.** The former passes back a short distance and then divides into three arteries which traverse the walls of the lung. The latter passes first forward and dorsally and then backward along the inner surface of the skin, sending branches to the head and the muscles of the body wall.

Exercise 22. Draw a semidiagrammatic sketch showing the distribution of these arteries so far as observed.

The middle arch, the **systemic,** supplies the greater part of the body with blood. The two sides of the arch pass dorsally, one on each side, around the œsophagus to the upper side of the body cavity, where they meet and form the **dorsal aorta,** or **aorta descendens.** This vessel runs just beneath the spinal column to

[1] The arterial system can be best studied after it has been injected; this should be done through the ventricle and the truncus arteriosus.

the hinder part of the body cavity, where it divides into two arteries, — the **iliacs**, — which go to the legs.

Lift up the stomach and find the aorta descendens; follow it forward to the meeting point of the two sides of the systemic arch, and then follow each side of the arch to the heart. Each side of the arch gives off the subclavian, occipito-vertebral, œsophageal, and laryngeal arteries, of which the subclavian is foremost in position.

The last three of these arteries leave the arch near together. The **subclavian** is the largest and supplies the shoulder and fore leg. Follow it and its branches. The **œsophageal** and **occipito-vertebral** are close together and go to the head, a branch of the latter — the **vertebral** — also passing back along the dorsal surface of the spinal column. The **laryngeal** arises in front of the others and goes to the head.

Just behind the point of union of the two sides of the systemic arch the dorsal aorta gives off the **cœliaco-mesenteric artery**. Observe that this large artery is a continuation of and receives most of the blood of the left systemic arch. The dorsal aorta thus receives most of its blood from the right arch.

The cœliaco-mesenteric artery supplies the stomach and intestine with blood. It soon divides into two branches, — the **cœliac artery** and the **anterior mesenteric**, the former supplying the stomach, liver, and pancreas, the latter the small intestine, rectum, and spleen.

Posteriorly to the cœliaco-mesenteric artery four to six pairs of **urogenital arteries** spring from the ventral surface of the dorsal aorta and go to the genital organs, kidneys, and fat bodies. Several pairs of small **lumbar arteries** also spring from the dorsal surface of the aorta and supply the dorsal body wall. Near the hinder end of the dorsal aorta the small median **posterior mesenteric artery** leaves its ventral surface and runs to the rectum.

The **common iliac arteries** — which are formed by the division of the dorsal aorta, — are large vessels which supply the hind legs. A short distance from its origin each gives off two small arteries, — the **hypogastric**, which supplies the rectum, bladder, and ventral body wall; and the **femoral**, which goes to the thigh.

After giving off these arteries the common iliac is known as the **sciatic artery**. Follow it and its branches into the leg.

Exercise 23. Draw a semidiagrammatic sketch showing these arteries so far as they have been observed.

Exercise 24. Draw a diagram of the entire arterial system.

The muscular system. Most muscles in the land vertebrates are attached at their two ends by means of tendons. One end is usually attached to a more or less fixed and the other to a more movable portion of the body, the former being called the **origin** of the muscle and the latter its **insertion**. The middle part of the muscle is called the **belly**; by its contraction the origin and insertion, and with them the skeletal pieces to which they are attached, are brought nearer together. Muscles are usually attached to the bones and cartilages; thick fibrous membranes, called **aponeuroses**, which often cover muscles and other organs, may, however, serve the same purpose.

Kill a frog and completely remove the skin from the body, without injuring any of the muscles. Inasmuch as they are more or less transparent when fresh, it is well to let the animal lie in alcohol or formalin before the muscles are studied.

Fasten the frog on its back, with its head away from you, by means of a pin through the tip of the nose and one through each foot, and, without cutting anything, study the muscles of the ventral side of the body. On the head the broad, thin **submandibular muscle** — the fibers of which are transverse in direction — stretches across from one side of the lower jaw to the other. A median tendon separates the right half of it from the left half. A narrow strand of muscle, the **subhyoid**, lies at the hinder end of the submandibular, with fibers parallel to its fibers and attached to it in the medial area. The lateral ends of the subhyoid find their origin in the hyoid cartilage.

At the forward end of the trunk is a group of four muscles which radiate from the base of the fore leg on each side toward the medial area of the body and may be called the **pectoral group**. Beneath the medial ends of these muscles between the fore legs

will be seen the delicate **sternum**, or breastbone. The foremost of these muscles is the **coraco-radial.** It is a wide muscle, the hinder half of which is concealed beneath the muscle next behind it. From its distal end a long tendon passes along the humerus to the forearm. The function of this muscle is to bend the forearm.

The other three muscles of this group are divisions of the **pectoral muscle.** The anterior two divisions, like the coraco-radial, have their origin in the breastbone near the median line. The hindermost division, which is the largest, has its origin in the outer edge of the broad aponeurosis, which occupies the median area of the abdomen. All the divisions of the pectoral muscle have their insertion near the proximal end of the humerus in the upper arm and serve to bend the arm back.

Lying in front of the pectorals is the **deltoid muscle.** It consists of two principal portions, — an anterior and a posterior portion, — both of which arise near the median line along the forward border of the pectorals. They are inserted in the humerus and cover the insertions of the pectoral muscles. Determine the action of the deltoid muscle.

Back of the breastbone are the **abdominal muscles,** which form the ventral and lateral walls of the abdomen. Three pairs are present, the rectus abdominis, the external oblique, and the transversus.

Extending from the hinder end of the breastbone to the hinder end of the trunk is the aponeurosis just mentioned, — a broad median band of connective tissue covering the midventral area of the abdomen. A similar aponeurosis is also present in the middorsal area.

The **rectus abdominis muscles** are a pair of longitudinal muscles which lie in the midventral area beneath the aponeurosis. A narrow tendinous band called the **linea alba** lies in the median line and separates the right from the left rectus. There are also present in these muscles four or five tendinous bands which divide them into segments. This segmentation, which also appears in the rectus abdominis of many higher vertebrates, including man, is an inheritance from the metameric condition of the body muscles in the fishes and the urodelan amphibians.

The **external oblique muscle** forms the lateral wall of the abdomen on each side. It is a broad, thin muscle which extends from the middorsal to the midventral aponeurosis, its fibers having an oblique direction. Immediately beneath this muscle is the **transversus**, the fibers of which have a transverse direction.

Exercise 25. Draw the ventral aspect of the body, showing these muscles.

Study the superficial muscles of the ventral surface of the hind leg. The longest muscle of the thigh is the **sartorius**. It is a long band which extends along the middle of the thigh from the pelvis to the proximal end of the shank. Just in front of it is a broad muscle — the **vastus internus** — which forms the anterior border of the thigh. It also forms the anterior portion of a threefold muscle, — the **triceps extensor femoris**, — which is the principal extensor muscle of the thigh. The other two portions of this muscle are on the upper side of the leg; they are the **rectus anticus femoris** and the **vastus externus**, — the latter being posterior to the former.

Posterior to the sartorius on the ventral surface are three muscles, — the **adductor magnus**, the **rectus internus major**, and the **rectus internus minor**, the latter of which forms the hinder margin of the thigh. These are all, together with the sartorius, flexors of the leg.

On the lower leg or shank the large muscle which forms the calf is the **gastrocnemius**. At its lower end is the **tendon of Achilles**, which passes over the ankle and is continued in the **plantar aponeurosis**, a broad tendinous band covering the sole of the foot. The front side of the shank is formed by the **tibialis anticus** muscle.

Exercise 26. Draw the ventral aspect of the hind leg.

Study the superficial muscles of the dorsal surface of the leg. The anterior half of the surface of the thigh is occupied by two muscles already noted, — the **rectus anticus femoris** and the **vastus externus**. Posterior to the last-named muscle are the **biceps**

femoris, the **semimembranosus**, and the **rectus internus minor**, — the latter forming the hinder margin of the leg.

On the shank will be seen the large **gastrocnemius**, forming the calf of the leg, the **tibialis anticus**, forming its anterior border, and the **peroneus** between the two.

Exercise 27. Draw the dorsal aspect of the leg.

Without injuring the bones trace each of these muscles to its origin and insertion and determine which muscles are extensors and which are flexors.

The skeletal system. This system is made up of two portions, the **exoskeleton** and the **endoskeleton**. The **exoskeleton** in vertebrates consists of the hardened bony or horny structures which develop in the skin and furnish an external protection to the animal. These structures are very poorly represented in the anuran amphibians. The skin is naked, no bony or horny scales or other hardened integumental structures being present. The toes are also without claws. The only exoskeletal structures are the teeth and certain bones called membrane bones which form a part of the skull. These bones are, however, so intimately joined with the other bones and cartilages of the skull that they will be studied in connection with them.

The **endoskeleton** consists of the bony and cartilaginous framework of the body. It may be divided into the **axial skeleton**, which includes the skull and the spinal column, and the **appendicular skeleton**, which includes the framework of the two pairs of appendages, i.e. the legs and the girdles which join them with the trunk. The breastbone may also be conveniently studied with the appendicular skeleton.

The appendicular skeleton. The anterior appendages consist of the **fore legs** and the **pectoral girdle**. This girdle is formed of a right and a left half which meet midventrally; here they enter into a close union with the breastbone and form with it a bony and cartilaginous ring which almost completely encircles the forward part of the trunk.

Each half of the pectoral girdle supports one of the fore legs and is composed of two portions, — a **dorsal** and a **ventral portion**.

The former portion consists of two skeletal pieces of nearly equal size,—the **suprascapula** and the **scapula**,—which lie respectively on the dorsal and lateral sides of the body. The suprascapula — the dorsal half — is a broad, thin plate which extends upward over the spinal column. Its broad, free dorsal end is composed of cartilage; the remainder of it is bone. The scapula is an elongated plate of bone which extends from the suprascapula to the ventral side of the body.

The ventral portion of the pectoral girdle consists of two bony and three cartilaginous skeletal pieces. The two bones are the **coracoid** and the **clavicle**, the former being the larger and the more posterior in position, and extending from the scapula to the midventral line. Joining them and the scapula is an irregular cartilaginous mass called the **paraglenoid cartilage**, in the hinder side of which is a depression, the **glenoid cavity**, in which the humerus articulates. Lying along the entire hinder surface of the clavicle is a slender strip of cartilage, the **procoracoid**, and at the medial end of the coracoid and clavicle is another narrow strip, the **epicoracoid cartilage**, which joins the like cartilage of the opposite side in the median line.

The **breastbone**, or **sternum**, lies in the medial area and consists of two portions, — the **sternum** and the **episternum**, — each of which is made up of a bone and a cartilage. The sternum lies immediately back of the coracoids. The bony half is in front of the cartilaginous portion, which is a broad, thin, bilobed plate. The episternum lies in front of the clavicles. The bony half is behind the cartilaginous portion, which is a thin, round plate.

Remove the pectoral girdle with the fore leg from the body. Inasmuch as it is not joined with the vertebral column it may be removed by freeing it from the muscles in which it is imbedded. First locate accurately the delicate cartilaginous portions of the sternum and the episternum; carefully locate also the delicate suprascapula on each side of the body. Insert then the blade of a small scalpel under the suprascapula on one side and free it from the muscles which lie over it. Pass the scalpel down to the scapula and then to the ventral portion of the pectoral girdle. Do the same on the opposite side of the body,

and finally remove the entire girdle with the breastbone from the body. Disarticulate and remove the two fore legs and very carefully clean away the muscles.

Exercise 28. Draw an outline sketch of the pectoral girdle and breastbone, representing them in one plane; carefully label all their parts.

The fore leg. The skeleton of the fore leg is composed of three divisions, — a proximal, a middle, and a distal division.

The **proximal division**, or upper arm, is composed of a single bone, the **humerus**. The head of it, which is cartilaginous, fits in the glenoid cavity and forms the shoulder joint. Just below it on the ventral side is a prominent ridge called the **crista ventralis**, in which the pectoral muscles are inserted. At the distal end is a large round projection, on each side of which is a ridge forming the articular surface for the bone of the next division.

The **middle division**, or forearm, is composed of a single bone, the **radio-ulna**. It is formed by the fusion of the radius and ulna, the two bones which are present in the forearm of most vertebrates. The larger part of this bone is the radius. Its proximal end is concave, the projecting process on it being the **olecranon**, or elbow. Its distal end has two articular surfaces.

The **distal division** is composed of the **carpus** or **wrist** and the **hand**. The carpal bones are six in number, arranged in two rows, a proximal and a distal row. The hand is made up of five **digits**, of which the first digit, or thumb, is very small and rudimentary. Each of the other four digits is composed of two parts, — the **metacarpus**, the long proximal bone which articulates with the carpus; and the **phalanges**, two or three small bones which form the finger. The thumb contains a metacarpus alone.

Exercise 29. Draw the fore leg in outline, showing accurately all the bones and cartilages; label them all carefully.

The posterior appendages. These consist of the **hind legs**, and the **pelvic girdle** which joins them with the trunk.

The **pelvic girdle**, like the pectoral, is composed of a right and a left half which meet ventrally and form an arch. The dorsal

ends of the arch articulate with the last vertebra of the spinal column, while at its ventral end, on each side, is the **acetabulum**, the articular surface of the hind leg. Extending backward from the last vertebra between the two sides of the pelvic girdle is the long bone called the **urostyle**, which forms the hinder part of the spinal column.

Each half of the pelvic girdle is composed of two portions, a **dorsal** and **lateral portion** and a **ventral portion**. The former consists of the long, slightly arched **ilium**, which forms the side of the arch and articulates dorsally with the last vertebra. The ventral portion is disk-shaped and is composed of the ventral end of the ilium, a small triangular bone called the **ischium**, and a small triangular cartilage called the **pubis**; the pubis is anterior to the ischium in position. The ilium, ischium, and pubis correspond to the scapula, coracoid, and procoracoid, respectively, in the pectoral girdle.

Carefully strip the muscles from the pelvic girdle, disarticulate it from the vertebral column, and remove it and the hind legs from the body. Disarticulate the legs and thoroughly clean the pelvis.

Exercise 30. Draw two views of the pelvis on a scale of 2, one of the lateral aspect and one of the dorsal aspect.

The hind leg. The skeleton of this leg closely corresponds to that of the fore leg. It is made up of three divisions,— a proximal, a middle, and a distal division.

The **proximal division**, or thigh, is composed of a single bone, the **femur**, the head of which fits into the acetabulum and forms the hip joint.

The **middle division**, or shank, is composed of a single bone, the **tibio-fibula**. It is formed by the fusion of the tibia and the fibula, the two bones which are present in the shank of most vertebrates. The line of division between the two is very distinct.

The **distal division** is composed of the **tarsus** or **ankle** and the **foot**. The tarsal bones are five in number, arranged in two rows, — a proximal and a distal row. The proximal row consists of two long bones, — the **astragalus** and the **calcaneum**, — which are

united at both ends. The latter is on the inner side of the foot and corresponds to the heel bone. The distal row is composed of three very small bones. The foot is made up of six digits, of which one is supernumerary and rudimentary; the others are the five digits which characterize the typical vertebrate foot. The supernumerary digit is on the inner side of the foot and consists of from one to three small bones. Each of the other five is composed of two parts, — the **metatarsus**, a long bone which articulates with the tarsus; and the **phalanges**, two to four smaller bones which form the toe. The first digit on the inner side of the foot corresponds to the big toe.

Exercise 31. Draw the ventral aspect of the leg on a scale of 2, showing accurately the outlines of the bones and cartilages.

The axial skeleton; the vertebral column. Strip the muscles from the back. Disarticulate the head from the trunk.

The vertebral column is composed of nine **vertebræ** and a long unsegmented bone called the **urostyle**, which forms its posterior portion. Four regions may be distinguished in it, — a **cervical** region, consisting of the first vertebra; a **thoraco-lumbar** region, consisting of the succeeding seven vertebræ; a **sacral** region, consisting of the last vertebra; and the **urostyle**, which represents a caudal region.

A vertebra is made up of the following parts: the **centrum**, or **body**, which is the cylindrical ventral portion; the **neural arch**, on the dorsal side of the centrum, which with it forms the neural canal; and the **transverse processes**, a pair of long lateral projections. The neural arch is made up of a pair of **neural processes**, which form its sides, and the median **neural spine**, or **spinous process**, which forms its roof. On the anterior surface of the neural arch is a pair of articular projections called the **prezygapophyses**; on the posterior surface is a pair of corresponding **postzygapophyses**. It is by these projections that the vertebræ are locked together. Note the difference in size in the transverse processes of the various vertebræ.

The first or cervical vertebra is called the **atlas**. It differs from the other vertebræ principally in that it has no transverse

processes (although occasionally they have been found), no prezygapophyses, and a thinner centrum. On its anterior surface is a pair of depressions into which fit the articular processes of the skull,—the condyles. The last vertebra, or **sacrum**, has large transverse processes with which the pelvic girdle articulates. It lacks postzygapophyses, and on the hinder surface of the centrum is a pair of prominences which articulate with the urostyle.

Between each two vertebræ on each side and between the ninth vertebra and the urostyle is an interval called the **intervertebral foramen**, through which a spinal nerve passes. In the urostyle on each side near the forward end is the foramen of the posterior spinal nerve.

Exercise 32. Draw a view of the ventral aspect of the vertebral column.

Exercise 33. Remove the second vertebra, clean it thoroughly, and draw a view of its hinder end.

The **skull** is composed of two regions, — the **cranium** and the **visceral skeleton**. The former incloses and protects the brain and the organs of special sense; the latter surrounds the mouth and pharynx, forming the framework of the jaws and tongue.

Both of these regions are composed exclusively of cartilage at an early period of the life of the animal, and certain portions of them remain cartilaginous. As the young animal develops, however, certain parts of the cartilage are replaced by bone. Besides these **cartilage bones**, as they are called, other bones also make their appearance which develop not in cartilage but in the skin and in connective-tissue membranes which cover the skull; these are called **membrane bones**. Thus, so far as the material of which it is made up is concerned, the skull is composed of cartilage, cartilage bones, and membrane bones.

We shall begin with the study of the **lower jaw** and the **hyoid apparatus** which supports the tongue. These structures belong to the visceral skeleton. The **hyoid** is a thin plate of cartilage, with a pair of long anterior and a pair of short

posterior projections, which is imbedded in the muscles of the lower jaw. The thin plate is called the **body** of the hyoid. The anterior projections — or **anterior cornua** — are slender, cylindrical cartilages which extend first backward to the hinder end of the lower jaw, and then upward to the base of the cranium; the **posterior cornua** are a pair of straight, bony rods which extend back from the hinder end of the body of the hyoid.

The **lower jaw**, or **mandible**, is a paired structure which is composed on each side of two bones called the **angular** and the **dentary**, and a cartilage. The latter is called **Meckel's cartilage**: it forms the primitive mandible at the time in the development of the animal when the entire skull is cartilaginous, and persists as the axis of the adult mandible. Its hinder end is widened and articulates with the upper jaw.

The greater part of Meckel's cartilage, however, is not free, but is ensheathed by two long membrane bones, — the **angular** and the **dentary**, just mentioned. The former of these bones covers the ventral and medial sides of the cartilage along almost its entire extent; on the outer side the hinder part of the cartilage is still exposed. The dentary bone consists of two portions, — a long, flat lateral, and a small medial portion. The former covers the outer side of most of the forward half of Meckel's cartilage; the latter is much smaller and lies at the forward end of the cartilage. The mandible is without teeth.

Without disarticulating the lower jaw, carefully dissect the hyoid apparatus from the floor of the mouth.

Exercise 34. Draw the hyoid apparatus on a large scale.

Exercise 35. Remove and clean the mandible and draw the dorsal aspect.

Thoroughly clean the remainder of the skull but do not remove the tympanum; the process is expedited by boiling it a short time.

Observe the great flatness and breadth of the skull. At its hinder end is the **foramen magnum**, the large opening through

which the spinal cord enters the brain cavity. The cranium, which protects the brain and the special sense organs, is the narrow medial portion of the skull. On each side of it is the large oval opening in which the eye lies. The arch-shaped sides of the skull are formed by the upper jaw and other portions of the visceral skeleton.

This part of the skull, like that already examined, is composed of cartilage and bone, the cartilage forming the primitive skull, the bone being either cartilage bone, which replaces the cartilage in certain places, or membrane bone which may cover or incase it.

The **cranial bones** fall into two distinct groups, — those forming the brain case, or **cranium proper**, and those forming the **capsules** of the **special sense organs**. The primitive cartilaginous cranium, which is partly replaced or covered by these bones, persists throughout the life of the animal in great part, and appears on the surface in a number of places. In skulls which have been allowed to become dry this cartilage will have disappeared.

The **cranium proper** contains the following bones. At the posterior end of the skull and surrounding the foramen magnum are the two **exoccipital bones**; they are cartilage bones. Each exoccipital bears on its hinder surface a convex articular projection, — the **occipital condyle**, — by which the skull articulates with the atlas. At the side of each exoccipital will be seen a portion of the primitive cartilage.

The pair of long flat bones which form the roof of the cranium and lie directly in front of the occipitals are the **fronto-parietal bones**; they are membrane bones which lie on top of the primitive cartilage. They may be raised up if the skull has not been allowed to become dry and the cartilage exposed. Note the three large openings present in it. The anterior ends of the fronto-parietals overlap a bony ring which encircles the forward end of the brain case; this is the **ethmoid**, a cartilage bone.

The ventral portion of the cranium is formed by two bones, — the **ethmoid**, just mentioned, and the **parasphenoid** or **parabasal**. The latter is a large T-shaped membrane bone which covers the entire ventral portion of the primitive cartilaginous cranium

and overlaps the ethmoid; its lateral portions extend to the auditory capsules. At the sides of it, back of the ethmoid, will be seen the primitive cartilage. The large foramen of the optic nerve will be seen in the side of the cranium between the fronto-parietal and the parasphenoid.

The special sense capsules. These are the auditory capsules at the hinder end of the skull and the nasal capsules at its forward end. The optic capsules do not ossify; they are largely membranous, with delicate cartilaginous plates in the sclera.

The **auditory capsules** are fused with the sides of the cranium proper and consist largely of cartilage. On the ventral side of the skull the lateral projections of the parasphenoid bone cover them. On the dorsal and anterior sides a cartilage bone called the **proötic** is present; it will be seen abutting the hinder part of the fronto-parietal bone. Between the proötic and parasphenoid bones is the large foramen of the trigeminal nerve.

Ventral to the proötic on the side of the skull is a depression; at the bottom of this is a large hole called the **fenestra ovalis,** which looks inside the auditory capsule. The depression is the **tympanic cavity,** — the middle ear of higher vertebrates, — which in the fresh skull is covered laterally by the **tympanic membrane,** or **ear drum.** The fenestra ovalis is closed by a minute cartilage called the **operculum,** which, in turn, is joined with the tympanic membrane by a small bony and cartilaginous rod called the **columella.** These two small structures, like the ossicles of the mammalian ear, convey the sound waves from the tympanic membrane to the inner ear. Skulls from which the tympanic membrane has been removed have often lost them.

The two **nasal capsules** lie side by side, fused with the anterior end of the cranium proper, and are also composed largely of cartilage. The ringlike ethmoid bone, which, as we have seen, forms the anterior end of the brain case, also forms the posterior end of the nasal capsules. Two pairs of membrane bones are present in these capsules, the dorsal **nasals** and the ventral **vomers.** The former are a pair of large bones which lie in a transverse position covering the cartilage just in front of the ethmoid; the latter are a pair of bones also in front of the ethmoid, on

the ventral surface of the skull, each bone bearing a group of small teeth.

The **upper jaw** and the other remaining portions of the visceral skeleton still remain to be described. The upper jaw forms two distinct arches, an outer or **maxillary arch,** and an inner or **palatopterygoid arch,** — the former consisting of three and the latter of two membrane bones on each side.

The three bones of the maxillary arch, on each side, are the **quadratojugal,** the small posterior bone; the **maxillary,** the long thin bone which bears most of the teeth; and the **premaxillary,** the small anterior bone which forms the anterior end of the skull and also bears teeth.

The two bones of the palatopterygoid arch, on each side, are the **pterygoid** and the **palatine.** The former is a large bone which lies at the hinder end of the skull, medial to the quadratojugal and the maxillary, and is best seen on the ventral surface. It has three ends, — its forward end going to the maxillary bone, its hinder end to the quadratojugal, and its medial end to the parasphenoid. The palatine is a slender bone which lies on the ventral surface and extends from the maxillary at the forward end of the pterygoid transversely to the ethmoid.

The bones and cartilages by which the lower jaw is suspended from the cranium are called the **suspensorium.** In the frog it is formed on each side by a small cartilage, — the **quadrate,** — and a membrane bone, — the **paraquadratum** or **squamosal.** The quadrate lies at the extreme latero-posterior end of the skull, in close connection with the quadratojugal bone and between the pterygoid and squamosal; the lower jaw articulates with its outer surface. The squamosal is a T-shaped bone which lies on the dorsal surface of the skull in the region of the auditory capsule; it supports the tympanic membrane.

Exercise 36. Draw a view of the dorsal aspect of the skull. Show accurately the outlines of the bones and cartilages, and indicate by a difference in color or by shading which are cartilage bones and which are membrane bones.

Exercise 37. Draw a similar view of the ventral aspect.

CHAPTER III

REPTILES

A TURTLE

Many species of land and fresh-water turtles occur in the eastern and central United States. The following table will aid in identifying most of the common species.[1]

A_1. Turtles with shell poorly ossified; body covered with a leathery skin in which scales are lacking.

Aspidonectes spinifer, the soft-shell turtle. Carapace round, spotted; plastron nearly white; legs and feet mottled; nostrils terminal; aquatic.

Amyda mutica, the leather turtle. A depression along median line of carapace; nostrils not terminal; in Great Lakes and upper Mississippi.

A_2. Turtles with well-ossified carapace; scales present in skin.

1. *Family Testudinidæ.* Carapace strongly arched; plastron broad and composed of 12 plates; toes joined by skin, only the blunt claws projecting.

   Testudo carolina, the Carolina gopher of the Southern States; burrows in the ground.

2. *Family Kinosternidæ.* Plastron large, with 7, 9, or 11 plates.

   a_1. *Kinosternum pennsylvanicum*, the small mud turtle. Shell dusky brown; head dark, with light spots; aquatic, but also found on the land; not so common as the following species; length 4 inches.

   a_2. *Aramochelys odorata*, the musk turtle. Shell dusky, sometimes spotted; neck with two yellow stripes on each side; with odor of musk; aquatic and common; length 6 inches.

3. *Family Emydæ.* Plastron with 12 plates.

   a_1. *Chelopus guttatus*, the spotted turtle. Black, with yellow spots; aquatic.

   a_2. *Chelopus insculptus*, the wood turtle. Carapace with keel, its plates marked with concentric striæ; both terrestrial and aquatic.

   a_3. *Chrysemys picta*, the painted turtle. Greenish black; plates edged with yellow; marginal plate marked with red; aquatic.

   a_4. *Cistudo carolina*, the box turtle. Yellowish brown, with blotches of yellow; plastron with hinge; terrestrial.

4. *Family Chelydridæ.* Plastron small, with 9 plates.

   Chelydra serpentina, the snapping turtle. Length up to 3 feet; aquatic.

[1] These descriptions have been modified from *Bulletin No. 51* of the New York Museum.

Two specimens will be needed for a complete dissection, — one for the study of the outer form, the viscera including the heart and the main blood vessels, the sympathetic and spinal nerves, and the skeleton, and one for the brain and cranial nerves and the smaller blood vessels. The sex of the turtle may usually be determined by the condition of the plastron, which in the male is flat or concave, and in the female slightly convex. The animal may be killed by being placed under a bell jar together with a wad of cotton soaked with chloroform or ether: several hours may elapse before it is dead.

Observe the form and color of the animal; note if the color markings are bilaterally symmetrical. Turtles are sharply distinguished from other vertebrates by the possession of a hard case or shell within which the animal can withdraw the head, tail, and legs more or less completely. The shell is composed of flattened plates of bone overlaid by thin plates of horn (tortoise shell), and is made up of two distinct portions, — the dorsal convex **carapace**, and the ventral, flattened **plastron**. In some turtles these two parts of the shell are not in contact with each other, while in others they are joined at the sides of the body.

The horny plates forming the outer surface of the carapace fall into several longitudinal rows. In most turtles the middle row consists of five **neural** and one **nuchal plate**; the latter is the foremost one in the row, and is wanting in some turtles. Lateral to this row on each side are four **costal** and twelve **marginal plates.** The posterior pair of marginals often become fused and form the unpaired **pygal plate.**

The plastron is usually covered by two rows of horny plates, with an additional pair on the bridge joining the carapace and plastron on each side.

In certain species of turtles concentric lines of growth may be seen in the horny plates of the shell, each ring representing a year's growth. The central nucleus of the plate shows its size when the animal was born.

Note the looseness of the skin of the neck, legs, and tail, which enables them to be drawn under the shell. If scales are present in the skin, note their variation in size.

The body of the turtle may be divided into four regions, — the **head**, **neck**, **trunk**, and **tail**. In most turtles the soft parts of all these regions are covered by horny scales which are similar in texture to the outer plates of the shell.

The **head** is compactly and very strongly built, with powerful jaws which are armed with horny plates instead of teeth, and contrasts markedly with the heads of amphibians and fishes. The **mouth** is ventral in position, and projecting in front of it is the snout, with the paired **nostrils** or **anterior nares** at its forward end. The **eyes** are prominent objects; they do not usually project from the head, but are protected above and below by bony ridges of the skull. Each is provided with three eyelids, — the thick **upper lid**, the more movable **lower lid**, and the **nictitating membrane**, — a translucent third lid which can be withdrawn into the anterior corner of the eye. Just back of the mouth is a slight circular depression which marks the position of the **tympanic membrane**, or **ear drum**, which lies on the outer surface of the head as it does in the frog.

The **neck** of the turtle is very long and flexible, a feature which is correlated with the heavy, awkward trunk.

The **trunk** is inclosed within the shell and bears the extremities. It shows a high degree of specialization. The spinal column and ribs have become flattened and help to form the shell, and the trunk muscles are wanting. Two pairs of **appendages** are present. Each leg is made up of three divisions, a **proximal**, a **middle**, and a **terminal division**, which correspond to the upper arm, the forearm, and the wrist and hand in the fore leg, and in the hind leg to the thigh, the shank, and the ankle and foot. Identify these divisions. Note the absence of a sole or walking surface on the feet; note the number of toes on each foot, and the claw on each toe. See if the toes are free or are joined by a membrane.

The **tail** is usually short and conical, and bears on its under side the **anus**, the opening of the cloaca. Note if the tail can be withdrawn under the shell.

Exercise 1. Make a drawing of the carapace, showing accurately the outlines of the horny plates, and label them.

Exercise 2. Make a similar drawing of the plastron.

Exercise 3. Draw a side view of the head on the scale of 2, showing accurately the outlines of the scales; label all the organs.

The mouth and pharynx. Open the mouth and disarticulate the lower jaw, after cutting the angle on each side. The mouth and pharynx form a single space; of this the pharynx is the hinder part, where the course of the air from the nostrils to the lungs crosses that of the food from the mouth to the stomach. Observe the form and arrangement of the plates covering the **jaws.** Find the **posterior nares,** the inner opening of the nostrils. Observe the floor of the mouth; note the shape and character of the **tongue,** and the opening of the **glottis** just behind it, through which air is admitted into the trachea and the lungs. Probe the glottis and note the two **arytenoid cartilages** which guard the opening and form a part of the larynx. Place a blowpipe in the glottis and inflate the lungs.

√ **Exercise 4.** Draw two sketches, — one of the floor and one of the roof of the mouth, on a scale of 3.

The internal organs. Open the body cavity in the following manner. Saw or cut through the bridge connecting the carapaçe and the plastron on each side, taking care not to cut too deeply. Then with the scalpel or scissors cut the skin where it is attached to the plastron, both in front and behind. Placing then the animal on its back,[1] carefully raise the plastron at the forward end, and with a scalpel cut the muscles where they are attached to its inner surface. Care must be taken to keep the blade at all times close to the plastron in order to avoid cutting the organs within. Remove the plastron, first noticing the glistening fibrous **periosteum** and the muscle attachments on its inner surface.

Observe the ventral aspect of the animal. A tough membrane — the peritoneum — will be seen covering the body cavity,

[1] If a towel be rolled up lengthwise and the roll be made into a ring, a stable support will be obtained to rest the animal upon during the dissection.

within which the viscera will be indistinctly visible. The **body cavity** is divided into two compartments, — the **abdominal cavity** and the **pericardial cavity**. The former is the larger and contains the liver, intestine, and most of the other viscera; it is lined by a membrane called the **peritoneum**. The latter contains only the heart and the base of the great blood vessels; it is formed by a membrane called the **pericardium**.

It will be observed that no abdominal muscles are present, which in other land vertebrates form the ventral and lateral walls of the abdomen; this feature is correlated with the presence of the shell. At the forward end are the large **pectoral muscles**; they cover the ventral portion of the pectoral girdle, the bony structure which supports the fore legs. At the hinder end are the large **pelvic muscles**, which cover the pelvis, — the structure supporting the hind legs. Both pectoral and pelvic girdles may be felt through these muscles. Imbedded in the muscles and the peritoneum may be seen the yellow fat. Within the pericardium will be seen the **heart**.

Imbedded in the peritoneum are the two prominent **abdominal veins** running in a diagonally longitudinal direction, and joined together by cross veins. It will be remembered that in amphibians a single median abdominal vein is present.

Exercise 5. Make a semidiagrammatic sketch of the ventral aspect of the animal, showing these organs, and carefully label all.

With sharp scissors cut away the entire ventral portion of the peritoneum and pericardium, together with the muscles attached to them. Note carefully where the abdominal veins leave the peritoneum and go to the liver. Do not cut the heart or any of the other organs in the body cavity.

Observe the organs as they lie in the body cavity in their natural positions. Just back of and beneath the pectoral muscles is the **heart**, and back of and at the sides of it is the large **liver**, the largest organ present. The liver consists of a right and a left lobe joined by a narrow bridge. Near the posterior edge of the right lobe may be seen the green **gall bladder**. Partly or

wholly beneath the outer edge of the left lobe and joined with it by a mesentery is the U-shaped **stomach**; while back of the liver are the coils of the **intestine.**

Lift up the intestine gently and note the membranous **mesentery** which joins it with the dorsal body wall and holds it in place. All the organs in the abdominal cavity are thus supported by mesenteries, which are folds of the peritoneum.

In the posterior portion of the abdominal cavity are the urogenital organs. If the animal be a male, the spheroid **testes,** which are usually of a yellow or reddish color, and the black **epididymis** which lies alongside and back of each one, will be seen. If a female, the granular, yellow **ovaries** and the tubular, convoluted oviducts will be seen. The condition and extent of these organs are, however, dependent upon the sexual condition of the animal. The **kidneys** are dark-red organs which lie against the dorsal body wall and will not yet be seen. At the hinder end of the abdominal cavity is the large bilobed **urinary bladder,** and back of it, beneath the pelvis, is the **cloaca,** which leads to the **anus.**

The large **lungs** are often visible in the abdominal cavity. They may always be brought into view by blowing into the glottis through a blowpipe.

Exercise 6. Make an outline drawing of the ventral aspect of the animal, showing the viscera as they lie in the body cavity.

The heart and its vessels. Carefully dissect away what remains of the ventral wall of the pericardium and the pectoral muscles, so as to bring into view the forward portion of the heart and the arteries springing from it.

The **heart** is made up of the transversely elongated ventricle, the two auricles, and the sinus venosus. The **ventricle** has thick muscular walls, and hence is usually not so deep red as the thinner-walled auricles and the sinus venosus. The **auricles** appear one on each side of the forward end of the ventricle. The ventricle is divided internally by a partial septum into two chambers which communicate with each other. Springing from its anterior border are the following arterial trunks: a

right and a **left aorta**, an **innominate artery**, and a **pulmonary artery**. Directly in front of these in the median line will be seen the small round **thyroid gland**; the **trachea**, or **windpipe**, may also be seen, and may be identified by its cartilaginous rings.

Of the arterial trunks the one which appears on the animal's right in the ventral aspect is the **innominate artery**. It branches almost immediately into the **right** and **left subclavian** and the **right** and **left carotid arteries**. Each subclavian, after giving off branches to the thyroid gland and the neck, becomes the **axillary artery**; this artery gives off branches to the pectoral muscles and finally as the **brachial artery** enters the leg. The carotids pass along the neck to the head.

Next to the innominate artery is the **left aorta**, which springs from the right side of the ventricle, passes to the left side of the body, turns dorsally and posteriorly, and finally joins the right aorta just beneath the spinal column, forming thus the dorsal aorta. The right aorta lies behind the innominate and will not be seen at present; it springs from the left side of the ventricle and passes to the right side of the body to aid in forming the dorsal aorta.

At the left of the aorta is the **pulmonary artery**. It divides immediately into a **right** and a **left pulmonary**, which go to the lungs.

These vessels will be studied in greater detail when the whole vascular system is dissected.

The **thymus gland** — a small, loose, yellowish mass of tissue — will be seen on each side lying dorsal to and in contact with the arterial trunks a short distance from the heart.

Exercise 7. Draw the ventral aspect of the heart and the arterial trunks and their branches so far as they have been observed.

Bend the heart forward and pin it there. Observe the right and left auricles; also the large sinus venosus, which is a large dark-colored vessel extending across the pericardial space and opening into the right auricle. Four large veins enter the sinus, bringing blood to the heart, — the **right** and **left precaval veins**, which bring blood from the forward part of the body; the **left hepatic vein**, from the left lobe of the liver; and the

postcaval vein, which brings blood from the hinder part of the body and the right lobe of the liver.

Observe the large **pulmonary vein,** which brings arterial blood to the left auricle from the lungs. It is formed by the union of a **right** and a **left pulmonary,** each of which may be seen lying alongside the bronchus on each side; the bronchi are the two large branches into which the trachea divides.

Exercise 8. Draw the dorsal aspect of the heart diagrammatically and the base of the great veins entering it.

The internal structure of the heart. Cut the great vessels entering and leaving the heart a short distance from their base and remove the heart from the body. Place it in water, with the dorsal side uppermost. Open the sinus venosus and wash out the blood in it. Note its thin walls. Find the large opening into the right auricle and the two valves guarding it. Carefully open the auricles by carrying a slit around their anterior edge and wash out the blood. Note the thin septum between the auricles, and the ridges in their walls. Pass a probe from the sinus venosus into the right auricle. Observe the opening from each auricle into the ventricle, one being on each side of the septum. Probe them.

Cut open the ventricle by carrying a slit along its anterior end through the auricular openings. Note its small cavity and the incomplete septum which divides it into two communicating spaces; note also the great thickness of the walls of the ventricle and the muscle ridges which project into the cavity. Find the openings of the large arteries into the ventricle by probing through them into it. Note that the pulmonary artery and the left aorta arise in the right side, and the right aorta and the innominate artery arise in the left side of the ventricle. Find, by using the blowpipe, the valves which guard the mouths of all these arteries. The circulation of the blood in the heart goes on as follows. Blood is brought to the heart by the caval veins and the pulmonary vein. The former bring venous blood from the various organs and tissues of the body to the sinus venosus, from which it goes to the right auricle to be pumped

finally into the right side of the ventricle. The pulmonary vein brings arterial blood from the lungs to the left auricle, from which it is pumped into the left side of the ventricle. The ventricle thus receives both kinds of blood, but the incomplete septum and the muscle ridges serve to prevent a complete mingling of them.

Blood leaves the heart by the four great arteries which take their rise in the anterior end of the ventricle. The two leaving the right side of the ventricle — the pulmonary and the left aorta — carry blood which is predominantly venous; this blood is carried by the pulmonary artery to the lungs, and by the left aorta largely to the stomach and intestine. The two arteries leaving the left side of the ventricle carry blood which is predominantly arterial to the remaining tissues and organs of the body.

Exercise 9. Draw a diagram showing the internal structure of the heart so far as observed.

The digestive system. This system is composed of the following organs: the mouth, pharynx, œsophagus, stomach, small intestine, large intestine, and cloaca, and the liver and pancreas, — two large, glandular organs which communicate with the small intestine.

With a scalpel cut through the pelvis in the median line. Inasmuch as the pelvic bones of the right and left sides are united in the median line by a cartilaginous symphysis, this will be easily done. Pull the two halves of the pelvis as far apart as possible[1] and separate the tissues beneath, thus exposing the **cloaca.**

Observe the extent of the cloaca. It will be seen to be a muscular tube passing beneath the pelvis. At its anterior end it is continuous with the rectum, the posterior division of the

[1] The pectoral and pelvic girdles may be conveniently kept out of the way while the dissection of the viscera is progressing as follows: Tie a stout string around the right pelvic girdle, pass it back over the carapace to the left pectoral girdle, then over the carapace to the right pectoral girdle and back again over the carapace to the left pelvic girdle. Pull it as tight as possible around all of these girdles and fasten it to the last one.

large intestine. The large urinary bladder is joined with its ventral wall by a narrow neck. The urinary and genital ducts join its dorsal wall, and the penis, in the male, is a specialized portion of its ventral wall.

Turn the **liver** forward and note the **stomach** beneath its left border. The anterior end of the stomach, where the œsophagus joins it, is the **cardiac end**; its posterior end, where it opens into the small intestine, is the **pyloric end**, and is marked by a constriction. The anterior end of the **small intestine**, which lies between the pylorus and the bile duct, is called the **duodenum**. Note the **gall bladder** in the right lobe of the liver, and the **bile duct** which joins it with the duodenum. The green bile may often be squeezed into this duct from the gall bladder. Note the **pancreas**, a pinkish organ which extends along the duodenum, and the **pancreatic duct** which joins it with the duodenum.

Exercise 10. Draw the dorsal aspect of the liver, together with the stomach, duodenum, and pancreas.

Cut the intestine loose from its mesentery as far forward as the bile duct, which must be preserved. Do this by lifting the intestine up with forceps and cutting the mesentery where it joins it. Note the great length of the small intestine. The **large intestine** contains three divisions, — the **cæcum**, a short, thick, blind gut at its forward end, and the **colon** and the **rectum** which form the greater part of it. The rectum is sometimes wider than the colon and is continuous posteriorly with the **cloaca**. Lying near the colon in the mesentery is the dark-red **spleen**; it is not a part of this system.

Free the liver from its connection with the lungs and other organs which lie dorsal to it, but be careful not to cut the bile duct. Cut the mesentery which joins the stomach with the liver. Observe the **cardiac end** of the stomach and the **œsophagus**. Follow the latter to the head. Stretch out the digestive tract on the dissecting board, with the liver and pancreas still attached to it.

Exercise 11. Make a drawing of the entire digestive tract, showing the relative lengths of the different divisions; carefully label all.

Cut the rectum and the œsophagus and remove the digestive tract. Slit open the rectum and the colon, also the stomach and the duodenum, and observe the folds of the mucous membrane.

The respiratory system. The large **lungs** have already been noticed lying against the inner surface of the carapace. Observe their exact extent. From each lung a tube called the **bronchus** passes ventrally and anteriorly, the two bronchi joining to form the **trachea**, or windpipe. Note the cartilaginous rings which prevent the bronchi and the trachea from collapsing. Trace the trachea forward to the **glottis**, its opening into the pharynx.

The forward end of the trachea is formed by the **larynx**; this contains a number of cartilages and has for its principal function the control of the passage of air into and out of the lungs. In the turtle it is composed of a large posterior cartilaginous ring, the **crico-thyroid cartilage**, and a pair of small cartilages, the **arytenoids**, which guard the opening of the glottis. Cut open a lung and examine its inner texture. Note the large open spaces in it.

Exercise 12. Draw a diagram showing the respiratory system.

The urogenital system. Observe the **cloaca** passing to the **anus**; observe the rectum and the **bladder**. Cut a hole in the bladder and probe through it into the cloaca. Probe through the anus into the bladder.

If the animal be a **male**, note the large **penis** in the cloaca. Widen the opening of the anus, if necessary, and observe that the penis is a specialized portion of the ventral cloacal wall. Note the groove along the middorsal surface of the penis and the enlargement at its free end.

Free the bladder from its attachments with the surrounding organs, but do not sever its connection with the cloaca. Raise the bladder and observe the two yellow **testes**, and beside and behind each the black **epididymis**, which is the terminal portion of the vas deferens. Trace the **vas deferens** to the cloaca. Lift up the testis with forceps and observe the **vasa efferentia**, the fine tubes which connect it with the epididymis.

If the animal be a **female**, the paired **ovaries** will be seen in the hinder part of the body cavity, filled with the round, yellow

ova. A pair of **oviducts** is present, one on each side of the median line. Each oviduct is a long tube which opens posteriorly into the cloaca; its posterior end is enlarged, forming a **uterus.** Its anterior end opens by a broad mouth into the body cavity. Straighten out one of the oviducts, cutting the fold of the peritoneum in which it lies. Find its mouth; if it is hard to find, cut a hole in it and probe forward. In a similar way probe backward into the cloaca.

Exercise 13. Make a semidiagrammatic drawing of the genital organs.

Remove the genital organs. The dark-red **kidneys** will be exposed lying close to the dorsal body wall. Along the median border of each is an elongated yellow patch, — the **suprarenal bodies.** Trace the short **ureter** to the cloaca on each side. It is formed by the union of a number of ducts on the ventral surface of the kidney. Note the exact point where the ureter joins the kidney. Slit open the entire cloaca and note the mouths of the ureters and the genital ducts.

Exercise 14. Make a drawing of the urinary organs.

Remove the lungs and the urogenital organs from the body. Observe the great **retractor muscles** of the head and neck by means of which these structures may be drawn under the shell. Observe those of the pelvis.

The nervous system. This system is made up of the following parts: (1) the **central nervous system,** consisting of the brain and the spinal cord; (2) the **peripheral nervous system,** consisting of (*a*) the paired cranial and spinal nerves which spring from the central nervous system and join it with the sense organs, muscles, and other organs, and (*b*) the sympathetic nervous system, which lies, for the most part, in the body cavity and is connected by branches with the spinal nerves and with the various viscera; and (3) the **organs of special sense.**

We shall study first the **spinal nerves** and the **sympathetic nervous system.** The spinal nerves spring from the spinal cord and

pass through the intervertebral foramina of the spinal column to the muscles of the neck and trunk and the inner surface of the carapace. The sympathetic nervous system consists of a pair of longitudinal nerves lying one on each side of the spinal column, each nerve containing ganglia at intervals corresponding to the spinal nerves. Branch nerves connect each ganglion with a spinal nerve, and others pass to the various viscera.

Note the spinal nerves, which extend as white threads across the inner surface of the carapace from the vertebral column to its outer border. Six or seven pairs will be seen. Each nerve consists of two main strands lying side by side. The spinal nerves of the neck, with the exception of the first pair, may be seen by pushing aside the retractor muscles on the neck. The posterior four or five pairs of cervical nerves form, together with a branch from the first spinal nerve of the trunk, the **brachial plexus**, a network of nerves from which arise the nerves which supply the fore leg.

Look for the sympathetic nerves on the sides of the great retractor muscles of the head and neck and on the surface of the vertebral column. The delicate white cord will be seen on each side with ganglionic enlargements. Follow it forward to the brachial plexus, — then across this plexus and on the side of the neck, where it will be seen to lie along the inner side of a larger nerve, which is the vagus. Follow it to the head.

Observe carefully the branches which connect each sympathetic ganglion with a spinal nerve, also those which pass off from the longitudinal cord and the ganglia to the various organs of the trunk. Expose the whole plexus and note which spinal nerves it is made up of. Find the nerves which go to the shoulder and arm and follow them as far as possible. Note the relation of the sympathetic nerve to the brachial plexus.

Exercise 15. Draw a diagram of the brachial plexus and the nerves proceeding from it, and the anterior portion of the sympathetic system, so far as observed.

Follow the longitudinal sympathetic nerve posteriorly. Expose the posterior spinal nerves and the **lumbo-sacral plexus**. This

plexus is usually made up of the last six spinal nerves of the trunk and gives rise to the nerves which supply the hind legs and the muscles of the pelvis. Follow these nerves as far as possible.

Exercise 16. Draw a diagram of this plexus and the nerves springing from it, and the posterior portion of the sympathetic system, so far as observed.

The special sense organs. The **ear** contains two regions, the inner ear or **membranous labyrinth**, and the middle ear or **tympanic cavity**, — the former being the essential organ of hearing which receives the auditory nerves, and the latter the space bounded externally by the tympanic membrane.

Carefully disarticulate and remove the head, taking care not to cut any of the bones of the skull or the cervical vertebræ.

Remove the skin which covers the tympanic membrane. This will be done easily if the head be first immersed a short time in hot water. Now will be seen the circular **tympanic membrane**, — a thin plate of cartilage filling the external opening of the tympanic cavity. With a sharp scalpel cut the tympanic membrane around its edge and, lifting it up, note the delicate, rodlike **columella**, which will be seen extending inward from it. Snip away the edges of the tympanic membrane and finally cut it from the columella, exposing the cavity of the middle ear.

This will be seen to be a large space which extends back from the opening to the hinder end of the skull. Probe it. The columella extends from the tympanic membrane to a point on the ventral wall of the cavity, where it will be seen entering a long canal just large enough to contain it; at the inner end of this canal the columella expands and is applied to the **fenestra ovalis**, the opening into the inner ear. The inner end of the columella and the fenestra ovalis will not be seen. Just beneath the columella is the slitlike inner opening of the **Eustachian tube**; probe it with a bristle and find its opening into the pharynx.

The columella is a bone which has cartilaginous ends. Its function is to conduct the sound waves to the inner ear.

The inner ear, or membranous labyrinth, will not be studied in this dissection.

Exercise 17. Draw a diagrammatic sketch of the tympanic cavity on a large scale.

The central nervous system and the cranial nerves will be studied in another animal.

The skeletal system. This system of organs is made up of two portions, — the **exoskeleton**, which is dermal in origin, and the **endoskeleton**, which is the internal bony and cartilaginous framework of the body.

The **exoskeleton** consists of the horny dermal plates (the tortoise shell) and scales which cover the external surface of the body, and also the bony dermal plates which underlie the horny plates and help form the shell. The bony portion of the shell is not composed of these dermal bones alone but also includes certain portions of the endoskeleton, — namely, the trunk vertebræ, most of the ribs, and perhaps the clavicle, which are more or less completely fused with the dermal bones. The exoskeleton also includes the claws and the horny covering of the jaws.

The **endoskeleton** is made up of the **axial skeleton**, which includes the skull and the vertebral column and ribs, and the **appendicular skeleton**, which includes the framework of the limbs and the girdles by means of which they are firmly attached to the trunk. The limbs and their girdles are between the right and left rows of ribs in turtles; in all other vertebrates they lie external to the ribs.

The axial skeleton. Disarticulate the neck and remove it with the head from the carapace. Disarticulate and remove also the pectoral and pelvic girdles with the legs, and the tail.

The **vertebral column** contains three regions, — the neck, trunk, and tail. The **trunk region** consists of the vertebræ and the ribs, which enter into the formation of the carapace. It will be first studied.

Boil the carapace until the flesh still remaining on it can be easily removed. Care must be taken not to boil it so long that it will fall to pieces.

The carapace. Peel off the horny plates and note that they do not coincide with the bony plates beneath. Observe the arrangement of the bony plates as seen on the outer surface. Note which of these plates are fused with the trunk vertebræ and which with the ribs.

The medial row of plates is composed of the single anterior **nuchal** plate, followed by a row of **vertebral plates** with each of which is fused the dorsal portion of a vertebra, and one or more posterior **pygal plates.** At each side of the median row is a row of **costal plates,** with which the ribs are fused, and lateral to them are the **marginal plates.** Certain of the latter plates, in most turtles, extend ventrally and meet the plastron.

Exercise 18. Make an outline drawing of the dorsal surface of the bony plates of the carapace.

Study the inner surface of the carapace. Note the centra of the vertebræ which project beneath the vertebral plates with which they are fused. Note also the ribs which are fused with the costal plates. Note the difference between the first pair of ribs and those following. The last two vertebræ form the **sacrum,** which supports the hinder extremities.

Exercise 19. Draw the ventral aspect of the anterior three and also of the posterior two vertebræ of the carapace, with their ribs and the dermal plates with which they are fused.

Separate the plates of the carapace from one another and observe carefully the difference in structure between the first and second vertebræ. Note the articular surfaces on the first vertebra with which the posterior cervical vertebra articulates. Study also the costal and marginal plates. Note the sutures on all these plates.

The plastron. Peel off the horny plates. Two rows of bony plates will be seen, between which is a single small median plate. The anterior pair of plates are called the **epiplastrons,** and are believed to be homologous with the clavicles of other vertebrates. The median plate is the **entoplastron,** and is thought to be homologous with the episternum. The two middle pairs are

the **hyoplastrons** and the **hypoplastrons**, and the posterior pair are the **xiphiplastrons**.

Exercise 20. Draw an outline of the plates of the plastron.

The cervical vertebræ. Disarticulate the head from the neck, being careful not to injure the hyoid apparatus, the cartilaginous support of the tongue which is imbedded in the muscles of the lower jaw. Thoroughly clean the vertebræ of the neck and string them on a string in the proper order so as not to lose the sequence. The neck contains eight vertebræ which are remarkable for the variety of form which characterizes them. They fall into two groups, one of which contains the first and second vertebræ; the other contains the remaining six. The first two vertebræ form the support of the skull. The first one is called the **atlas**. It is a ring-shaped bone which is made up of three pieces, — two dorsolateral portions representing the neural arch, and a ventral portion. On its anterior surface is a depression in which the condyle of the skull articulates. The second vertebra is called the **axis**. It is made up of a cylindrical centrum and a neural arch through which the spinal cord runs. At the anterior end of the neural arch is a pair of articular processes — the **prezygapophyses** — and at its posterior end are the corresponding **postzygapophyses**. Short transverse processes and no ribs are present. Projecting forward from the anterior end of the centrum is the **odontoid process**. It lies within the arch of the atlas, the centrum of which it represents.

The posterior six cervical vertebræ are similar to the axis, except that they do not have the odontoid process. Study each one separately and note the points in which they differ from one another, especially in the form of the end surfaces of the centra.

Exercise 21. Draw on a scale of 3 or 4 the anterior end of the atlas; a side view of the axis and atlas; and the anterior end of the fourth vertebra.

Study the **caudal vertebræ**. Note the rudimentary ribs on the anterior ones. Are the centra procœlous, opisthocœlous, or amphicœlous?

The skull. Disarticulate the lower jaw and remove it together with the hyoid apparatus, being careful not to injure the latter. The skull is made up of two regions, the **cranium** and the **visceral skeleton**, the former constituting the brain case together with the special sense capsules, and the latter being made up of the bones and cartilages of the upper jaw, the suspensorium of the lower jaw, the lower jaw, and the hyoid apparatus.

We shall begin with the study of the lower jaw and the hyoid apparatus, which supports the tongue. The lower jaw, or **mandible**, is a V-shaped structure composed of five bones and a cartilage on each side. The bones are very firmly knit together, and a prolonged boiling may be necessary to make the sutures visible. Before this is done, however, observe the shape of the mandible, the cutting edge of which is covered by horn, the prominent coronary process on the upper surface of each side, and the articular surface at the hinder end of each side. Note also on the inner surface of each side a long groove in which lies a rod of cartilage. This is Meckel's cartilage.

The bones in the mandible are the following: the **dentary**, which is fused with its fellow of the opposite side and forms the front part of the jaw and most of the outer and lower surfaces; the **coronoid**, which forms the coronary process and serves as the principal surface of attachment for the strong jaw muscles; the **splenial**, which forms the greater part of the inner surface from the coronary process to the hinder end; the **angular**, a thin strip beneath the splenial; the **supra-angular**, a small plate above the angular at the hinder end; and the **articular**, which forms the greater part of the hinder end. The last-named bone is an ossification in the hinder end of Meckel's cartilage; the others are all membrane bones.

Exercise 22. Draw the lower jaw, showing the outlines of these bones.

The **hyoid apparatus** consists of (*a*) a median flattened **body**, usually a cartilaginous plate the dorsal surface of which is concave and holds the larynx, and (*b*) two pairs of lateral projections, or **cornua**, which are usually partly of bone. At the lateral

border of the anterior portion of the body of the hyoid on each side is also, in many turtles, a small cartilaginous projection.

Exercise 23. Draw the hyoid apparatus.

Thoroughly clean the remainder of the skull; in removing the tympanic membrane note the **columella**, a minute rod of bone which extends directly inward from it. Observe the general character of the skull. The cranial bones, which form the greater part of it, and the visceral bones, which form the upper jaw and a part of the roof of the mouth, are firmly joined by sutures and together form a very strong and compact whole.

Observe the **nostrils** or **anterior nares** at the anterior end, and the **posterior nares** in the roof of the mouth; also the circular orbits. Note at the hinder end of the skull the large **foramen magnum** and the long bony spine projecting above it. Note that the brain cavity is much narrower than the whole skull, which is very wide posteriorly, and that an extensive arch is present on each side just back of the orbit which partially covers a space, — the **temporal fossa.** This fossa is continuous with the orbit in front and extends backward as a wide groove; it contains the powerful muscle which closes the lower jaw. Note the large external ear opening and the position of the tympanic membrane. Note the **condyle** by which the skull articulates with the vertebral column; also the articular surface of the lower jaw.

Study first the dorsal surface of the skull. Beginning at the anterior end, the medial bones are the paired **prefrontals, frontals,** and **parietals,** and the median **supraoccipital,** — the latter bone bearing the long spine which projects back from the base of the skull. Identify these bones. Lateral to the medial bones on each side are the following: the **maxilla,** which forms the lower and the anterior borders of the orbit; the **postfrontal,** which adjoins the frontal and forms the upper portion of the posterior border of the orbit; the **jugal,** which is just ventral to the postfrontal and forms the lower portion of the posterior border of the orbit; the **quadratojugal,** which is just back of the jugal and forms the front side of the circular opening covered by the tympanic membrane; the **squamosal,** a large bone adjoining

the parietal, which forms the prominent latero-posterior end of the skull; the **quadrate**, which forms the hinder side of the circular tympanic opening and terminates below in the articular surface of the lower jaw; the **proötic**, a small bone between the quadrate and the parietal, which is pierced by the foramen of the external carotid artery; the **opisthotic**, a small bone directly back of the proötic and between the squamosal and the supraoccipital; the **epiotic**, a small bone which is fused with the lateral edge of the supraoccipital and appears as a part of it, lying in contact with the opisthotic, proötic, and parietal.

Exercise 24. Make a drawing of the dorsal aspect of the skull on a large scale, showing the outlines of these bones. Carefully label all.

Study the ventral surface of the skull. The bones which appear in the medial area are the following: the paired **premaxillæ**, which form the anterior end; the paired **maxillæ**, which are directly back of the premaxillæ and with them support the horny biting surface of the jaws; the median **vomer**, a slender bone between the maxillæ, which helps form the walls of the posterior nares; the paired **palatines**, between the hinder ends of the maxillæ, which hold the vomer between them and help form the roof of the mouth; the paired **pterygoids**, large bones immediately back of the palatines, which meet each other in the median line and help form the roof of the mouth; the median **basisphenoid**, immediately back of the pterygoids; the median **basioccipital**, which is back of the basisphenoid and forms the hinder end of the skull. Lateral to the hinder end of the pterygoid on each side is the **quadrate**, back of which is the **squamosal**; medial to the hinder part of the last-named bone is the **opisthotic**, and immediately back of this, the **exoccipital**. Note that the occipital condyle is formed of three portions, and determine the bones of which they are a part.

Exercise 25. Make a drawing of the ventral aspect of the skull on a large scale, showing the outlines of these bones.

Cut away the bony arch at the left side of the skull and expose the temporal fossa. Identify the bones which have already been observed. Along the ventral margin of the parietal note the small **alisphenoid bone.** The large foramen at the inner side of the quadrate is for the passage of the trigeminal nerve. Note that the two orbits communicate with each other, not being separated by a bony septum; the membranous septum which was present is usually destroyed in the cleaning. Note also that the anterior end of the brain case is not bony.

Exercise 26. Make a drawing on a large scale of the lateral aspect of the skull.

Study the posterior aspect of the skull. Identify the bones and other features already mentioned. At the side of the condyle are two foramina, the nearer and smaller of which being that of the hypoglossal nerve and the larger that of the vagus and the spinal accessory nerves.

Exercise 27. Make a drawing on a large scale of the posterior aspect of the skull.

Of the bones just studied the following belong to the **visceral skeleton,** forming the upper jaw and the suspensorium of the lower jaw: the premaxillæ, maxillæ, jugals, palatines, pterygoids, quadratojugals, quadrates, and squamosals, — of which the only cartilage bones are the quadrates. The remaining bones form the cranium; they fall into two categories, — those of the **cranium proper,** or brain case, and those of the **special sense capsules.**

The bones of the **cranium proper** fall rather easily into three groups: a posterior group, comprising the occipital bones; a middle group, comprising the basisphenoid, the alisphenoids, and the parietals; and an anterior group, comprising the frontal bones. Of these the occipital bones and the basisphenoid are cartilage bones, the others being membrane bones. The presphenoid, orbitosphenoid, and ethmoid elements of the skull remain cartilaginous in the turtle and thus will not appear in a skull that has been cleaned.

The **special sense capsules** are the auditory, optic, and nasal. These capsules, which are entirely cartilaginous or membranous in the embryo, remain largely in this condition throughout the life of the animal. In the **auditory capsule** the opisthotic, proötic, and epiotic — all of which are cartilage bones — appear on each side, the epiotic becoming fused with the supraoccipital. The **optic capsule** is entirely membranous. The **nasal capsule** is cartilaginous, the only bone developing in it being the vomer, a membrane bone. Nasals do not occur.

Boil the skull until the bones can be separated from one another. Take them apart and examine each carefully, identifying the bones belonging to the various regions of the skull.

The appendicular skeleton; the anterior extremities. The anterior extremities are composed of the **pectoral girdle** and the **fore limbs.** The skeleton of the former is made up of three bones on each side of the body, — a cylindrical dorsal bone, the **scapula**, and the two ventral bones, the **procoracoid** and the **coracoid**, the latter being behind the former. The scapula and the procoracoid are continuous, forming a single piece; the distal ends of the ventral bones are joined by a ligament. At the meeting point of these three bones is the **glenoid fossa**, the depression in which the humerus articulates.

The **fore leg** contains three divisions, — a proximal, a middle, and a distal division. The skeleton of the **proximal division**, or upper arm, is a single bone, the **humerus.** That of the **middle division**, or fore arm, contains the **radius** and the **ulna**, of which the former is preaxial and extends farther distally than the latter. The **distal division** is the wrist and hand. The skeleton of the **wrist**, or **carpus**, is made up of nine bones, of which three — the **ulnar**, **intermedial**, and **radial** — form a transverse row at the distal end of the radius and ulna, and five, which are called the **carpals**, form a row at the proximal end of the hand. The first carpal bone abuts on the radial. Adjoining the ulnar is an additional bone, the **pisiform**, which differs from the others in that it is a membrane bone, being formed as an ossification in a tendon. It is thought by some to be a rudiment of a sixth finger and is homologous to a similar bone in mammals.

The skeleton of the **hand** is made up of five **digits**, each of which is composed of a single proximal **metacarpal bone** and several finger joints or **phalanges.**

Exercise 28. Make a sketch of the anterior extremity, showing accurately the outlines of all these bones.

The posterior extremities. These are composed of the **pelvic girdle** and the **hind limbs.** The skeleton of the former is composed of three bones on each side, the dorsal **ilium**, and the ventral **pubis** and **ischium**, the former of which is in front of the latter. At the point of meeting of these three bones is the **acetabulum**, the depression in which the femur articulates. The dorsal end of the ilium articulates with the sacrum. The two pubic bones are joined in the median line by a narrow cartilaginous plate. The two ischial bones are smaller than the pubes and contiguous to them, and are also joined by a median cartilage.

The skeleton of the hind leg is made up of three divisions,—a proximal, a middle, and a distal division. The **proximal division**, or thigh, is composed of a single bone, the **femur**, the head of which fits into the acetabulum. The **middle division**, or shank, contains two bones, the **tibia** and **fibula**, the former being somewhat larger than the latter and preaxial in position. The **distal division** is composed of the ankle and the foot. The **ankle** or **tarsus** contains six small bones in two rows, the proximal row consisting of the smaller **fibular** and the larger **astragalus**, and the distal row of four **tarsal bones**, of which the largest has been formed by the fusion of the original fourth and fifth tarsals. The foot is composed of five **digits**, each of which contains a proximal **metatarsal bone** and several **phalanges.**

Exercise 29. Make a sketch of the posterior extremity, showing accurately the outlines of all these bones.

A fresh animal will be needed for the study of the brain and the blood vessels. Kill the animal and remove the plastron, as directed on page 136. Very carefully chip away a small part of the wall of the brain case so as to admit fluids into it. The brain can be studied to the greatest advantage after it has been hardened

in strong alcohol or in formalin. We shall, consequently, study the blood vessels first in this specimen and allow the brain to be hardening while they are being dissected.

The vascular system. This is made up of the following organs: (1) the **heart**; (2) the **arteries**, the vessels through which the blood is carried away from the heart; (3) the **veins**, the vessels through which the blood returns to the heart; and (4) the **capillaries**, the minute vessels connecting the veins and arteries.

The heart and the great veins and arteries which are in direct connection with it have already been studied. We shall now make a detailed study of the veins, and after them of the arteries.[1]

The **veins** may be divided into two groups: (1) the **systemic veins**, those which bring venous blood from the various organs and tissues to the sinus venosus, with their branches; and (2) the **pulmonary veins**, which enter the left auricle, bringing arterial blood from the lungs.

The veins of the first group may be further subdivided into (*a*) the **caval veins** and their branches, which bring blood directly to the sinus venosus; and (*b*) the **portal veins**, which carry it first to the liver and kidneys.

The portal veins. Two systems of portal veins are present: the **hepatic portal veins**, by which blood is carried from the stomach, intestine, and spleen to the liver; and the **renal portal veins**, which carry the blood of the hind quarters to the kidneys. These two systems are joined by the two **abdominal veins** which, as we have already seen, lie in the ventral abdominal wall and are very conspicuous when the plastron is removed.

Follow the course of the abdominal veins and their branches. At a point opposite the heart they leave the peritoneum and pass dorsally (inward) to the liver; this will hardly be seen at present on account of the opacity of the peritoneum. At the angle where

[1] Both the veins and the arteries can be studied to advantage in the turtle without being injected; this is especially true of the veins, which are colored dark by the blood which remains in them after the death of the animal. If the veins are injected, however, it must be done at several places, — in the portal or one of the abdominal veins and in the postcaval. The entire arterial system is easily injected through the ventricle of the heart.

this turn is made each abdominal vein receives an anterior vein from the pectoral muscles. With forceps pull these muscles loose from those beneath and trace the further course of this vein and its branches. It will be seen to come from the outer side of the pectoral girdle and to receive a large branch from the inner side of this girdle.

Pressing aside or removing, if necessary, the pelvic muscles, study the distribution of the posterior branches of the abdominal vein and the **renal portal system**. The vein will be seen to turn laterally near the anterior border of the pelvis and to pass along or just beneath this border toward the hind leg. Not far from the turn it receives a branch which may be traced backward over the pelvis, near the hinder border of which it is joined by a vein connecting it with the corresponding vein on the opposite side of the body. Trace its further course.

Return now to the main vein and trace it to the muscles which join the leg with the inner surface of the carapace, lifting up the pelvis and its muscles and separating them from the peritoneum beneath. Cut the skin where it joins the carapace around the hinder end of the animal, lift it up, and without cutting anything, separate the muscles and other tissues beneath it, until the large veins are seen. The abdominal vein may be in this manner traced to its origin, and will be seen to be formed by the union of three large veins, — the **femoral vein** from the leg, the **caudal vein** from the tail, and the **renal portal vein** which passes dorsally to the kidney. Trace the renal portal vein medially to the kidney, and the other two veins as far as possible.

With sharp scissors cut away the entire ventral portion of the peritoneum, leaving, however, the abdominal veins intact. Observe the anterior ends of these veins where they pass dorsally and enter the liver.

Exercise 30. Draw a diagram showing the abdominal veins and their anterior and posterior branches and the renal portal system, so far as observed.

Study the **hepatic portal system**. Cut the two abdominal veins. Raise the right lobe of the liver and examine its dorsal surface.

Observe the gall bladder near its posterior border and follow the bile duct which joins it with the intestine. If the animal has been freshly killed, the green bile may be squeezed into this duct from the gall bladder. Lift up the left lobe of the liver; note the mesentery which joins it with the stomach, and the numerous **gastric veins** which run from the wall of the stomach to the liver. Observe again the pyloric end of the stomach and the whitish pancreas which extends from it along the intestine to the bile duct.

With a sharp scalpel or scissors cut the mesentery just mentioned, freeing the liver from the stomach and the anterior end of the intestine as far back as the bile duct, taking care, however, not to cut the large blood vessels near it. Turn the entire liver forward and pin it there, thus exposing its dorsal surface.

Observe the large and conspicuous branches of the **portal vein** which run across the dorsal surface of the liver, partly buried in its substance. Find the point where the branches which traverse the two main liver lobes meet; the single large vein thus formed is the **portal**. Trace it backward; it will be found to receive a number of veins, of which the largest are the **pancreatic vein** from the pancreas, and the **mesenteric vein** from the mesentery. The latter vein is formed of a number of veins which lie in the mesentery and bring blood from the wall of the intestine. Lift up the intestine and trace the mesenteric vein and its branches, without, however, cutting the mesentery. Note that the mesenteric veins are accompanied by smaller vessels,—the mesenteric arteries. Note the **gastric veins**, which enter the left branch of the portal vein from the wall of the stomach.

During this examination the **spleen** will be seen — a dark-red organ the size of a pea — lying in the mesentery alongside the intestine and near the point where the mesenteric vein is formed by the union of its intestinal branches. The **postcaval** — the largest vein in the body—will also be seen near this place, and must not be confused with the veins of the portal system. It comes from between the kidneys in the hinder part of the body cavity, passes forward close to the spleen and the right lung, and enters the right lobe of the liver.

Joining the portal vein also are the abdominal veins, which have already been studied.

Exercise 31. Draw a diagram of the hepatic portal system, so far as observed.

The caval veins. Cut the intestine back of the bile duct and also at the end of the rectum, and remove it from the body. Bend the heart forward and pin it there, exposing its dorsal surface and the base of the large caval veins.

Identify the ventricle, the two auricles, and the sinus venosus. Four large veins enter the sinus: the **right** and **left precaval veins**, bringing blood from the forward part of the body; the left **hepatic** vein, from the left lobe of the liver; and the **postcaval vein**, which brings blood from the hinder part of the body and the right lobe of the liver.

Trace the left **precaval vein**; it will be seen to be formed by the union of two veins, — the **subclavian** coming from the fore leg and the **internal jugular** from the side of the neck. Cut the skin between the forward border of the shell and the shoulder, find these veins, and follow them as far as possible.

Trace the **postcaval vein.** We have already seen that it passes through the right lobe of the liver and receives the right hepatic vein not far from the heart. It may now be followed from the hinder border of this right lobe to a middorsal position in the abdominal cavity, where it lies between the kidneys. Here it is formed by the union of a number of **renal veins** from the kidneys and **genital veins** from the genital glands.

Exercise 32. Draw a diagram representing the caval veins and their branches, so far as observed.

The arteries. Make a midventral incision in the skin and expose the organs of the neck. Study the blood vessels which spring from the anterior side of the ventricle, carefully dissecting them free from the tissues surrounding them. Three large arteries will be seen, side by side. The one on the animal's right is the **innominate artery**; it divides at once into the **right** and **left subclavian arteries** which go to the fore legs, and the **right** and

left carotid arteries which go to the head. In the angle formed by the branching of these arteries lies the round **thyroid gland.** Next to the innominate artery is the **left aorta,** which springs from the right side of the ventricle and passes to the left side of the body. Next to it and on the left is the **pulmonary artery,** which branches at once into the **right** and **left pulmonaries.**

After these arteries have been dissected free from the surrounding tissues, the **right aorta** will be seen beneath the innominate artery; it springs from the left side of the ventricle and passes to the right side of the body; the right and left pulmonaries will also be seen. The right and left aortas meet on the dorsal side of the body cavity and form the **dorsal aorta.**

Follow these arteries and their main branches, beginning with the subclavian.

The **subclavian artery** gives off several small branches, of which one passes at once to the thyroid gland, one runs along the ventral side and one along the dorsal side of the neck; it then becomes the **axillary artery,** which passes above the brachial nerve plexus, and finally, as the **brachial artery,** goes to the leg. The axillary artery gives off a branch, the **internal mammary,** which passes to the outer border of the carapace and runs backward along it to the hinder part of the body, where it anastomoses with the epigastric artery, a branch of the dorsal aorta.

The **carotid artery** is smaller than the subclavian, and may be traced forward to the head. In the greater part of its course it lies alongside the large vagus nerve, the much smaller sympathetic nerve, and the internal jugular vein. The **thymus glands** will also be seen; they are a pair of loose, yellowish masses of tissue at the base of the neck.

Follow, now, the **pulmonary artery** and the aorta on the left side of the animal. Push the stomach and left lobe of the liver to the animal's right and trace the **left pulmonary artery** to the lung. Note again the **left pulmonary vein,** and trace it from the lung to the heart. Trace also the **left aorta** to its union on the dorsal side with the **right aorta.** It gives off the following large arteries: the **cœliac artery,** which passes to the wall of the stomach, where it breaks into branches; the **anterior mesenteric**

artery which supplies almost the entire intestine, its numerous branches lying alongside those of the mesenteric vein; the **gastroduodenal artery**, which divides into two main branches and supplies the stomach, duodenum, and pancreas. Trace all of these arteries and their branches.

In young animals and sometimes in adults a small cross artery will be seen on each side, which unites the aorta with the pulmonary artery; it is called the **ductus Botalli**.

Follow the **dorsal aorta** now to the hinder end of the body cavity, where it passes between the kidneys alongside the postcaval vein, and behind them divides into the **right** and **left common iliac arteries**. A number of small arteries will be seen leaving the dorsal aorta, one of which, the **epigastric artery**, passes to the lateral border of the carapace, on each side, where it runs forward and finally anastomoses with the internal mammary artery. Trace these small arteries.

Each common iliac artery divides very soon into the **internal** and the **external iliacs**. The former gives off branches which supply the colon, rectum, and cloaca. The latter gives off branches to the muscles of the pelvis, and then, as the **sciatic artery**, supplies the leg. Follow the sciatic and its branches.

Exercise 33. Draw a diagram of the arterial system so far as observed.

Exercise 34. Draw a diagram of the entire vascular system.

The brain and the cranial nerves. Cut off the head. With a strong scalpel or bone forceps cut the bone from the dorsal side of the cranium and also partly from the lateral sides; carefully remove the dura mater — the connective-tissue membrane covering the brain — and study its dorsal surface. Its anterior division — the **cerebrum** — makes up more than half the brain; it is composed of the two **hemispheres**, from the forward end of which project the **olfactory lobes**. Between the posterior ends of the hemispheres is the delicate **pineal body**, the only part of the **thalamencephalon** — the second division of the brain — which appears. Back of this appear the paired **optic lobes**, the dorsal portion of

the midbrain, — the third division. Behind the optic lobes are the **cerebellum** and the **medulla oblongata**, — the fourth and fifth divisions. Remove the vascular **choroid plexus**, the dark-colored membrane which forms the dorsal surface of the medulla, when a triangular depression — the fourth ventricle of the brain — will be exposed.

Exercise 35. Draw the dorsal aspect of the brain on a scale of 3 or 4.

Remove enough of the side of the cranium to expose the side of the brain. Carefully tilt the brain to one side and study the twelve pairs of **cranial nerves**. The first pair — the **olfactory nerves** — proceeds from the olfactory lobes of the hemispheres and goes to the nasal capsules. The second pair — the **optic nerves** — springs from the ventral surface of the thalamencephalon and proceeds to the eyes. The third and fourth nerves — the **oculomotor** and the **trochlear** — are very small nerves which pass from the posterior portion of the midbrain to the muscles of the eyeballs, the oculomotor arising from the ventral and the trochlear from the lateral surface of the midbrain.

The fifth nerve — the **trigeminus** — is a large nerve which leaves the side of the anterior end of the medulla oblongata; it passes forward and soon swells to form the **Gasserian ganglion**, which lies on the inner surface of the skull and may have been removed with it. From this ganglion three nerves spring and pass to the outside of the skull; these are the **ophthalmic**, which passes forward and enters the orbit just back of the optic nerve; the **maxillary**, which also passes forward and enters the orbit, where it divides into two branches; and the **mandibular**, which passes out through the same foramen with the superior maxillary and is distributed to the muscles of the jaw.

The sixth nerve — the **abducens** — is a small nerve which arises from the ventral surface of the medulla near its anterior end and passes to the muscles of the eye. The seventh and eighth nerves — the **facial** and **auditory** — spring together from the side of the medulla back of the trigeminus, the former passing to the muscles of the upper jaw and the latter into the ear capsule.

The ninth nerve — the **glossopharyngeal** — arises from the side of the medulla and passes to the muscles of the tongue and pharynx. The tenth and eleventh nerves — the **vagus** or **pneumogastric** and the **spinal accessory** — arise each by a number of roots from the side of the medulla; the former passes along the side of the neck to the pharynx, larynx, lungs, and stomach; the latter goes to the muscles of the neck and shoulder. The twelfth nerve — the **hypoglossal** — arises from the ventral surface of the medulla near its hinder end and passes to the muscles of the tongue and throat.

Exercise 36. Draw the lateral aspect of the brain on a scale of 3 or 4, and show the origins and course of the cranial nerves, so far as observed.

Remove enough of the skull so that the brain can be taken out. Place it in a dish of alcohol or water and study its ventral surface. Identify the **hemispheres** and the **olfactory lobes**. On the ventral surface of the thalamencephalon is the **optic chiasma** and the **infundibulum**, — the latter bearing at its distal end the **hypophysis**. The ventral portion of the midbrain is formed by the **crura cerebri**. Behind this is the **medulla oblongata**.

Exercise 37. Draw the ventral aspect of the brain on a scale of 3 or 4.

CHAPTER IV

BIRDS

THE PIGEON

The domestic pigeon is one of the best birds for dissection because of its convenient size and the ease with which it can usually be obtained. All birds are, however, essentially alike in structure, and these directions may be used with the chicken, the sparrow, or any other common bird.

Two specimens will be needed for a complete dissection,— one for the study of the outer form and the viscera, and one for the muscles and the skeleton. They should be killed as needed by being placed in a closed jar with a little chloroform or ether, and during the dissection should be kept in a one per cent solution of formalin. Care should always be taken that the specimens be covered by the preserving fluid, otherwise they will mold; the fluid should also be changed as often as it becomes stale.

Study the external characters of the animal. The most distinctive feature of a bird is the feathers, which clothe almost the entire body and are so arranged on the fore limbs and tail as to enable it to fly. Feathers are highly specialized epidermal structures and are allied to reptilian scales; they are present in all birds, and in no other animals. Feathers are not only of great importance to the bird in enabling it to fly, but they are very effective in checking the radiation of heat from its body, as they form a warm outer covering. It is largely because of the development of feathers that birds have become warm-blooded animals. The ordinary temperature of a bird's body is about 105° Fahr., varying a few degrees in different species.

Note the three kinds of feathers, — the contour feathers, down feathers, and pinfeathers. The **contour feathers** form the outer

surface of the body and give it its outline; note their method of overlapping and the smooth surface they present to the air. The quills, which form the beating surface of the wings and the tail, are elongated contour feathers.

The **down feathers** are soft and fluffy; they clothe the nestlings and are also found between the contour feathers in the adult. The **pinfeathers**, or **filoplumes**, are hairlike structures which lie among the other feathers and will be seen when they are removed.

Note the arrangement of the feathers on the body. Observe first those parts which are entirely bare, as the bill, eyelids, etc. The greater part of the body is apparently covered by the contour feathers, but a careful examination will show that there are distinct feather tracts and other parts which have no feathers. These tracts can be distinguished better in a young pigeon or a sparrow than in an adult pigeon, in which they tend to run together. It will be seen that the down feathers and pinfeathers are present on the tracts not covered by contour feathers.

Besides the feathers, other epidermal structures are present which help form the outer covering of the body; these are the horny scales, plates, and claws on the legs and toes, and the horny covering of the beak.

Observe the color of the animal and determine if the color tracts are bilaterally symmetrical. In a wild state the color pattern of an animal has a strong tendency toward bilateral symmetry, but domestication changes the action of natural selection, which has given an animal its peculiar characters, and often results in the confusion of the color patterns. The coloration of the European rock pigeon, the wild ancestor of the domestic pigeon, is similar to that of the common slate-colored domestic pigeons.

Observe the general shape of the body. It is a compact, rigid structure, a laterally compressed ellipsoid in shape, with a long neck and large head, large wings, feet, and tail. The shape fits the animal to be propelled rapidly through the air. The neck of a bird is usually very flexible because the trunk is rigid, — a correlation we found also in the case of the turtle.

The large head indicates intelligence, the large wings and tail a powerful flight, and the strong feet ability to walk well.

The body may be divided into four regions, — the **head, neck, trunk,** and **tail.**

The head. This body division articulates with the vertebral column by a single condyle and consequently has great range of movement. It has a high, arched cranial or posterior portion and is prolonged anteriorly to form the conical beak, which is made up of the upper and lower jaws, and is the organ of prehension. Note that the upper jaw possesses considerable flexibility and is not so rigidly joined with the cranium as is the case in mammals and in the turtle. The **mouth** is large and is without lips. The **nostrils** or **external nares** are a pair of slits near the base of the upper beak and just in front of a swollen area called the **cere.** The **eyes** are large and round and each has three lids, an **upper** and **a lower lid,** — both movable, the latter more so than the former, — and **a nictitating membrane,** a third lid. This membrane is situated at the anterior corner of the eye, where it is entirely concealed when not in use, and moves back and forth. With fine forceps pull it over the eye. The opening of the **ear** is just behind the eye and leads to the tympanic cavity; note the feathers which guard the opening. There is no external ear.

The head of all modern birds is remarkable in that it contains no teeth and no strong masticatory muscles; a considerable weight is thus spared it. This is a feature which is also correlated with the great powers of flight which most birds possess. Flying is one of the most difficult and highly developed methods of locomotion among animals, and makes necessary a careful adjustment of the weights to be carried. It is very much to the advantage of a flying vertebrate that the heavier portions of the body be brought as near the center of gravity as possible, and that the various organs be lightly constructed.

Thus the teeth, which are composed of the densest and one of the heaviest tissues of the body, have entirely disappeared in the course of the evolution of the modern bird. But a grain-eating bird like the pigeon must chew its food, because only in

a finely reduced condition is the food digested quickly enough to furnish the needed amount of heat and energy. Instead, however, of the chewing being done in the mouth, as it is in the mammals, the other group of warm-blooded vertebrates, the performance of this function is removed to the gizzard, a part of the stomach, which is situated very near the center of gravity.

Another effect which has been correlated with the loss of teeth in the bird is the development of a greater intelligence. Inasmuch as the weight of the head is strictly limited by the conditions of the animal's existence, a larger brain could develop than would have been possible if the teeth, which characterized primitive birds, had not disappeared.

The long **neck** is loosely inclosed in the skin. Near the base of the neck is the **crop**, an expansion of the œsophagus for the storage of food; in it is also secreted the milklike substance called pigeon's milk, with which the nestlings are fed.

The **trunk** is made up of two subregions, — the **thoracic** and the **abdominal regions**; to the former belong the wings, to the latter the legs, by means of which the bird exercises its two very different methods of locomotion. Both of these subregions are rigid ones, inasmuch as the attachment of the locomotory organs to the trunk must be firm and solid; thus the whole trunk is a firm, boxlike structure. The viscera in the trunk are very compactly arranged, much more so than in the mammal, and are supported in the troughlike dorsal surface of the breastbone. On the ventral side of the thoracic region, on each side of the breastbone, — the keel of which can be felt in the median line, — are the great pectoral muscles, the principal muscles of flight. In some birds, as the humming bird, these muscles constitute more than half the bulk of the body; in the pigeon they form about a fourth.

The trunk contains the **air sacs**, which are large, thin-walled sacs lying among the other viscera, and communicating with the bronchi of the lungs and the hollow centers of many of the bones. These sacs are reservoirs of air; their function is somewhat obscure, but they probably help supply the lungs during

rapid flight when sufficient air could not be inspired through the nostrils to supply the demands of the system. Place a blowpipe in the glottis, at the root of the tongue, and blow the lungs full of air; it will be seen that the entire trunk swells out, all the air sacs being filled.

The **anus** — the external opening of the cloaca — is a transverse slit with thickened lips on the ventral surface of the trunk near the base of the tail; it will be seen when the feathers are removed.

The **tail** is short and wide; it has received the name of the **uropygium**. It is of great importance to the animal, as its long quills help to support it in the air and to direct the course of its flight. There are twelve of these tail quills in common pigeons; the number, however, varies in the different breeds. Besides these, the tail also bears the **tail coverts**, — small contour feathers at the base of the quills on both the dorsal and the ventral surfaces. The tail contains the **uropygial gland**, with the secretion of which the bird oils its feathers; its opening is on a large papilla on the dorsal surface of the tail. This is the only skin gland in the body.

The appendages. Two pairs are present, — an anterior pair, the **wings**, and a posterior pair, the **legs**. The wings, which are homologous to the fore legs of the other vertebrates, offer an extensive surface to the air; each is made up of three divisions, — the **proximal**, **middle**, and **distal**, — which correspond to the upper arm, the fore arm, and the wrist and hand. The hand contains three digits, of which the first is free, the second and third being fused together.

The upper arm is short and partly within the trunk, and usually does not bear wing quills. These are borne by the forearm and the hand, and are divided into two groups, — the **primary quills** and the **secondary quills**. The former are ten in number and are attached to the hand; the latter are about thirteen in number and are attached to the forearm. Besides these, a small tuft of feathers, which is independently movable, is present on the outer, forward side of the wing. These feathers are attached to the first digit, or thumb, and form what is called the

ala spuria. The shorter contour feathers on both dorsal and ventral surfaces at the base of the wing quills are the **wing coverts.**

The **legs** are each made up of three divisions, — the **proximal, middle,** and **distal,** — which correspond to the thigh, the shank, and the ankle and foot respectively. The thigh is within the skin of the trunk and does not project beneath it. The shank is the upper end of the drumstick; it is a stout, muscular structure which projects from the trunk. The distal division of the leg is composed of a vertical shaft and four toes. The shaft is the lower end of the drumstick and is formed by a fusion of the tarsal and metatarsal bones, and hence is equivalent to the ankle and foot. The toe directed backward is the first; the second toe is the inner one of the three directed forward. Observe the arrangement of the feathers and scales upon the leg and toes; observe the number of joints in each toe.

Exercise 1. Draw an outline of a side view of the animal with the wings closed, not putting in the separate feathers. Label all the parts carefully.

Exercise 2. Draw a dorsal view of the head.

Exercise 3. Extend one of the wings and draw its dorsal surface, showing the various groups of feathers.

Thoroughly pick the pigeon. This is done much more easily and quickly if the bird be first dipped in hot water. The picking had better be done in an opened towel to prevent the feathers from getting scattered.

Observe carefully the delicacy of the skin. Note the filoplumes, or pinfeathers. Observe also the shape of the body, the length of the neck, the large size of the pectoral muscles, and the form of the tail. Observe between the anterior ends of the pectoral muscles the V-shaped depression in which the crop lies; on each side of it one arm of the wishbone may be felt. Find the pore of the uropygial gland, and squeeze oil out of it. Note the shape of the anus and its thick, projecting lips.

Note the three divisions of the wing. In the distal division find the three digits, — the short, movable thumb which supports

the ala spuria, and the second and third digits which are grown together. Note the **alar membrane**, which lies in the angle between the upper arm and the fore arm. Note the three divisions of the leg.[1]

The mouth and pharynx. Open the mouth and cut through the angle of the jaw. Carry the cut back through the muscles of the head almost to the opening of the ear. Disarticulate the lower jaw and turn it down, exposing the cavity of the mouth and pharynx.

There will be seen to be a single space which lies between the edges of the bill and the œsophagus, that part of it within the bill being the mouth cavity, and the posterior part, the pharynx. This latter space is where the course of the respiratory air from the nostrils to the lungs crosses that of the food from the mouth to the stomach.

Note the long **tongue**, and its shape. Just back of it is the **glottis**, the opening into the larynx and the windpipe; note its shape and the character of its lips. Back of the glottis is a paired **transverse membrane** with fringed edges, projecting from the floor of the pharynx, behind which is the opening of the œsophagus. Note the two elongated plates which form the roof of the mouth, also the serrated medial edges of their hinder portion. Note the elongated, paired **posterior nares**, through which the nasal capsules open into the pharynx; they are in the roof of the pharynx opposite the glottis. Just behind them is the single median opening of the paired **Eustachian passages**, which join the pharynx with the tympanic cavity; pass a bristle through it. Note the paired folds in the roof of the pharynx opposite the fringed ventral folds, all of which guard the opening into the œsophagus.

Exercise 4. Draw a sketch of these structures on a scale of 2.

[1] If it is intended to inject the blood vessels, it must be done now. This is best performed by means of a fine cannula, through the brachial artery and the brachial vein, which will be seen on the inner surface of the wing, the vein being the larger of the two. The femoral artery and vein may also be easily injected; they will be seen in the leg by separating the muscles. The circulatory system can, however, with the exception of the smaller vessels, be easily studied without the aid of injection.

The internal organs; the air sacs. These sacs arise from the outer surface of the lungs and extend as thin-walled pockets among the viscera and the muscles, and beneath the skin; they also extend into many of the bones, such as the humerus, femur, sternum, and others. A branch of a bronchus leads directly to each sac.

Insert a blowpipe into the glottis and inflate the lungs and the air sacs.

There are several important sacs. The paired **abdominal sacs** lie near the dorsal wall of the abdominal cavity, dorsal to the intestine, coming near the ventral surface posteriorly; they join the hinder end of the lungs. The paired **posterior thoracic sacs** lie behind and beneath the lungs and along the outer sides of the abdominal sacs; they join the sides of the lungs. The **anterior thoracic sacs** lie in front of and partly beneath the posterior thoracic sacs; they join the ventral surface of the lungs. The **interclavicular sac** is a branched structure which lies beneath the anterior end of the breastbone and the clavicle; it joins each lung just in front of the main bronchus; on each side it is joined by an **axillary sac** which lies beneath the shoulder. The paired **cervical sacs** lie in front of the lungs, with the anterior ends of which they communicate.

It is impossible to dissect out these sacs without destroying the organs among which they lie. Some of them, however, can easily be seen. Lay bare the humerus, the large bone in the upper arm, and cut a hole in it. Insert the blowpipe in the glottis or in a slit in the trachea, and blow into the lungs. The air will be felt coming out of the humerus, which is a hollow bone containing a branch of the axillary sac.

Make a midventral incision through the abdominal wall from the hinder end of the breastbone to the anus; do this by lifting up the wall with forceps and cutting it with scissors. Make a transverse incision on each side along the hinder end of the breastbone and cut away the flaps of the abdominal wall. Inflate the lungs again; the abdominal sacs will be filled and brought into view. Note the great delicacy of their walls. Under the wings will be seen the axillary sacs, and beneath the crop, the interclavicular sac.

The viscera. Lay bare the breastbone, removing the pectoral muscles from it. Cut the breastbone loose from its attachments along its posterior and lateral margins. Lift it up gently and observe the **falciform ligament,** — a transparent, median mesentery which joins it with the organs beneath. Note the large **liver** beneath the hinder part of the breastbone. Cut the falciform ligament and, still lifting up the breastbone, note the large **heart** which lies in its concave dorsal surface. Entirely remove the breastbone from the body, cutting with scissors the ribs at its side and the bones of the shoulder girdle, which join the breastbone with the shoulder blade. Be careful to avoid cutting the blood vessels.

Observe the organs in the body cavity, but without disturbing them; note the compactness with which they are placed. The body cavity may be subdivided into two spaces, — the large **abdominal cavity**, which is lined by the glistening **peritoneum** and contains most of the viscera, and the **pericardial chamber**, which is formed by the **pericardium** and contains only the heart.

Observe the pericardium surrounding the heart. Back of it is the large two-lobed **liver**. Beneath and back of the left lobe is the **gizzard**. Covering the organs back of the liver is a membrane filled with fat. This is the **great omentum,** — the mesentery of the stomach, of which the falciform ligament is the anterior portion. Cut around the border of the great omentum and remove it; observe the coils of the small intestine, which fill the hinder part of the cavity, and the narrow **pancreas** which lies between two of its folds.

Exercise 5. Draw a semidiagrammatic sketch of the opened body cavity within an outline of the bird, and the organs as they lie in it; carefully label all.

The digestive system. This consists of the mouth, pharynx, œsophagus, glandular stomach, gizzard, small intestine, large intestine, cloaca, the salivary glands, liver, and pancreas.

Lift up the liver and find where the **small intestine** leaves the gizzard, in the middle of its medial surface. The anterior portion of the small intestine forms a great loop, called the

duodenum, within the bend of which lies the **pancreas**. Lift up this loop and note its extent. Follow the intestine to its hinder end so far as this is possible without cutting any of the organs except the walls of the air sacs. Note the **mesentery** of the intestine which joins its coils with the dorsal body wall; note also the large veins and arteries which lie in it.

Turn the liver forward and, without cutting anything, study its dorsal surface. The large **portal vein** will be seen, which enters the liver near the median plane and at once gives off branches to its lobes. Near this point are the two **bile ducts** which carry bile from the liver to the intestine. Find them. The longer duct is a large tube, about an inch in length, which runs from the liver to the right limb of the loop of the duodenum. The shorter duct is also large and enters the left limb not far from the gizzard.

Observe the shape of the pancreas, which lies in the duodenal loop. Find its three ducts; two of these leave the pancreas near its middle and enter the right limb of the loop, the third duct leaves the pancreas in front of the other two and passes forward to the right limb of the loop.

Exercise 6. Draw the dorsal aspect of the liver, showing the branching of the portal vein, the two bile ducts, the duodenum, and the pancreas and its ducts.

The vascular system. This is made up of the following organs: (1) the heart, (2) the arteries, (3) the veins, (4) the capillaries, and (5) the lymph vessels. The **heart** is composed of two auricles and two ventricles. Two systems of **arteries** are present: (*a*) the **pulmonary arteries**, which take venous blood from the right ventricle to the lungs to be aërated; and (*b*) the **systemic arteries**, which take arterial blood from the left ventricle to the various tissues and organs of the body. Two systems of veins are present: (*a*) the **pulmonary veins**, which bring arterial blood from the lungs to the left auricle; and (*b*) the **systemic veins**, which bring venous blood from the tissues and organs of the body to the right auricle.

The systemic veins may be further subdivided into two systems: these are (*a*) the **caval veins**, — those veins carrying blood directly to the heart, and their branches; and (*b*) the **portal systems** of veins, which carry blood from certain tissues and organs directly to the liver and kidneys, from which it is afterwards taken to the heart by the postcaval vein.

The portal veins. Two portal systems of veins are present, — the hepatic portal and the renal portal system.

The hepatic portal system. We have already seen where the hepatic portal vein enters the liver. This vein is very short, although one of the largest in the body; it will be seen to be formed by the union of three large veins, which with their branches are prominent objects in the intestinal mesentery. These are the **gastroduodenal vein**, which comes from the gizzard, the duodenum, and the small intestine; the **anterior mesenteric vein**, which comes from the small intestine and receives numerous branches; and the **posterior mesenteric vein**, which lies immediately dorsal to and parallel with the hinder part of the small intestine and the rectum, receiving small branches from them.

Without cutting the mesentery find these three veins and their chief branches. The first two are easily studied by turning over the various loops of the small intestine. In order to see the posterior mesenteric, press forward the gizzard and the entire small intestine. Note also in this connection the arteries which lie in the mesenteries accompanying the branches of these mesenteric veins.

The renal portal system. Lying against the dorsal body wall will be seen the large red kidneys, one on each side. The **posterior mesenteric vein** corresponds to the abdominal vein of reptiles and amphibians, although it differs from it somewhat in position, and joins the hepatic with the renal portal system. At its inner (dorsal) end this vein receives the small **caudal vein** and immediately divides into two short veins, the **right** and **left renal portals**; each of these goes directly into the hinder end of one of the kidneys, receiving first, however, from behind, the **internal iliac vein**.

The dissection of these veins will be completed when the kidneys are studied.

Exercise 7. Draw a diagram showing the portal veins, so far as observed.

The digestive system (*continued*). Straighten out the intestine by cutting its mesentery; leave, however, the duodenal loop uncut. Separate the liver and gizzard from the air sacs at their left and turn them toward the animal's right. The **glandular stomach** will be brought into view; it appears as a forward continuation of the **gizzard**. Trace it forward to the **œsophagus**, which enters it just dorsal to the anterior end of the heart. From this point the œsophagus runs forward to the pharynx; it will be studied later on.

Study the divisions of the digestive tract posterior to the œsophagus. The **glandular stomach** and the **gizzard** are, in birds, equivalent to the stomach of other vertebrates; in the former, digestion goes on, in the latter, food is ground up and prepared for digestion. The walls of the gizzard are very thick and muscular and its cavity is lined with a hard, ridged, cuticular membrane. Note the round red **spleen** by the glandular stomach.

The **intestine** begins at the gizzard and is divided into two portions, the **small intestine** and the **large intestine** or **rectum**. The small intestine is very long. Its anterior portion is the **duodenum**, which forms the loop inclosing the pancreas and receiving the bile and pancreatic ducts. Its posterior portion falls into two divisions of equal length, the anterior one of which is thicker than the posterior. The anterior end of the rectum is marked by a pair of small sacs, the **rectal diverticula**; it passes to the **cloaca**, — a short, wide sac which opens to the outside through the anus and receives also the discharges of the urinary and the genital organs.

The two intestinal glands — the liver and pancreas — have already been studied.

Exercise 8. Draw the digestive tract so far as observed.

Cut the stomach from the œsophagus with scissors; cut the bile and pancreatic ducts and free the stomach, gizzard, and

intestine of all their attachments with the liver and other organs, and remove them from the body; do not disturb the liver.

Cut open the glandular stomach and gizzard and the duodenum and observe their inner surface. Note the thick walls and the hard cuticular lining of the gizzard. Observe that its cavity can be tightly closed by a valve and shut off from that of the glandular stomach; also that the beginning of the duodenum lies close to the hinder end of the glandular stomach, and that when the gizzard is closed fluids would pass directly from the glandular stomach into the duodenum.

Exercise 9. Make a semidiagrammatic drawing of the opened glandular stomach, gizzard, and duodenum, showing these features.

Cut the rectum and remove the digestive tract from the body.

The urogenital system. The **urinary system** consists of a pair of kidneys, a pair of ureters, and the cloaca. Each **kidney** is made up of three lobes, which lie close against the dorsal body wall in the posterior part of the body cavity; the peritoneum passes over their ventral surface. Do not remove them. The **ureters** are a pair of slender tubes, each of which emerges from the hinder border of the anterior lobe of the kidney and passes along the ventral surface of the posterior two lobes, straight back to the dorsal wall of the cloaca, receiving branches along its course.

Lying on the ventral surface of each kidney is a small yellowish organ, the **suprarenal** or **adrenal body**. They are of problematical function, but do not belong to the urogenital system.

The genital system; the male. The **testes** are a pair of white, ovoid bodies which lie against the medial borders of the anterior lobes of the kidneys. Note the mesenterial fold which attaches each to the dorsal body wall. They are joined with the cloaca by the **vasa deferentia**, a pair of convoluted, slender tubes which pass posteriorly from the medial border of the testes along the ventral surface of the kidneys. They lie lateral to the ureters. The hinder end of each is dilated, forming a **vesicula seminalis**.

The female. But one ovary and oviduct are present, the left ones; those on the right side are present, however, in the embryo. The **ovary** is a granular organ which lies against the medial border of the anterior lobe of the left kidney, attached to it by a mesenterial fold; yellow ova of various sizes will usually be seen in it. The **oviduct** is a wide tube with thin walls anteriorly and thick walls posteriorly, which extends, suspended in a mesenterial fold, along the ventral surface of the left kidney and the dorsal body wall to the cloaca. Its anterior end opens into the body cavity by a much elongated, funnel-shaped orifice into which the ova pass when they escape from the ovary. A rudiment of the right oviduct is present in the form of a slender tube extending a short distance forward from the cloaca.

The oviduct secretes the white of the egg and the shell, as the ovum passes down it.

The absence of the right ovary and oviduct is an additional feature which is correlated with the bird's flight. The ovaries and oviducts are both bulky organs and much weight is saved by the elimination of those on the right side.

The **cloaca** is a broad, short tube which opens to the outside through the anus. It receives the rectum at its forward end; the two ureters and the genital ducts also empty into it. Cut it open by a slit along one side, wash it out, and study its interior. Find the openings of the organs just mentioned, and note their arrangement with reference to one another. Note that the rectum opens into the ventral wall of the cloaca and the urogenital ducts open into a shallow dorsal pocket. In young birds, and occasionally in adults, a glandular sac called the **bursa of Fabricius** is present in the dorsal wall; its function is unknown.

Exercise 10. Draw the urogenital tract and the cloaca.

The vascular system (*continued*); **the heart.** Remove carefully the delicate pericardium. The heart is of large size and conical in shape. It is divided into four chambers, — the two **auricles** and the two **ventricles**. The auricles form the anterior end of the heart and are marked off from the ventricles by a

line of fat. On the surface of the heart are seen small **coronary veins** which arise in the heart muscles themselves.

The great arteries. Issuing from the base of the heart between the two auricles are the two large **innominate arteries**; they together form a V, between the arms of which will be seen the trachea, or windpipe. Note near them a pair of slender muscles — the **tracheo-sternal muscles** — which converge to the ventral surface of the trachea. They arise on the inner surface of the sternum, which has been removed from the body; remove these muscles and thoroughly clean the arteries.

The innominate arteries do not arise directly from the heart, but from the **aorta**. This large vessel springs from the left ventricle, and at once giving off the two innominate arteries continues its course, first dorsally and then posteriorly, as the **dorsal aorta**; do not follow it at present.

Each of the innominate arteries, after a course of about a quarter of an inch, divides into two vessels, — the **carotid artery**, which runs directly forward to the head, and the **subclavian artery**. This latter artery is very short; it gives off the small **internal mammary artery**, and almost at once divides into the **brachial artery**, which runs to the shoulder and supplies the wing, and the **pectoral artery**, which supplies the pectoral muscles.

Follow the **carotid artery** forward. Carefully separate the œsophagus, with the crop, from the organs among which it lies; note the large blood vessels which go to the crop. Note the two long **thymus glands** which lie one on each side of the trachea along almost the entire length of the neck; they have the appearance of fat. Lying near the trachea also on each side are the **cervical artery**, the large **jugular vein**, and the **vagus nerve**, the latter of which appears as a white cord; do not dissect them yet.

The carotid artery runs just beneath the jugular vein about half an inch, and then gives off two branches, — the **vertebral artery**, which passes medially to the vertebrarterial canal of the cervical vertebræ in which it runs to the brain, and the **cervical artery**, which accompanies the vagus and the jugular vein to the head.

In the angle between the carotid and the cervical arteries on each side lies the small **thyroid gland**.

The main trunks of the two carotids now converge toward the median plane and pass through the muscles of the neck to a groove in the ventral surface of the center of the cervical vertebræ, along which they run forward. Near the head they diverge, and each passing to its own side soon divides into two arteries, — the **external carotid**, which supplies the outer portions of the head, and the **internal carotid**, which goes to the brain.

Study the **subclavian artery** and its branches. One of the latter, the **internal mammary artery**, passes backward along the inner surface of the ribs. Follow the **brachial** and **pectoral arteries**, and study their branching.

Issuing from the right ventricle is the **pulmonary artery**; it divides at once into the **right** and **left pulmonaries**, which lie directly dorsal to the innominate arteries and go to the lungs.

Exercise 11. Draw the ventral aspect of the heart and the vessels just described.

The great veins. Turn the apex of the heart forward and pin it there, and carefully but thoroughly clean its dorsal surface. Identify the right and left auricles and the right and left ventricles. Three large veins will be seen entering the right auricle,—the **right** and **left precaval veins** and the **postcaval vein**. If these are not seen readily, the two precavals may be found by following the large jugular veins, one of which is on each side of the neck, posteriorly. The **right precaval** is a very short vein which enters the right anterior border of the auricle. It is formed by the union of three large veins, which meet just in front of the auricle, — the right **brachial vein**, which comes from the wing; the right **pectoral**, which comes from the pectoral muscles; and the right **jugular vein**, which comes from the head. The pectoral vein receives at its proximal end the **internal mammary vein**, which lies alongside the mammary artery on the inner surface of the ribs.

The **left precaval** will be seen passing across the dorsal surface of the heart to the left side of the right auricle; it is formed by the union of the same veins as the right precaval.

Free these veins from the tissues surrounding them. Trace the jugular forward along the side of the neck, where it lies

close to the vagus or pneumogastric nerve and the cervical artery. Beneath the under surface of the skull the two jugulars are united by a transverse vein. Note the veins from the thymus gland and the crop which join the jugular, and note also the large **vertebral vein.** This vein brings blood from the brain and lies in the vertebrarterial canal together with the vertebral artery.

The **postcaval vein** is a large vessel which enters the right auricle directly from behind. It brings blood from the hinder part of the body and passes through the right lobe of the liver to the heart; do not follow it posteriorly at present.

Turn the heart over to the animal's right and pin it there; pull the heart gently forward and look for the **pulmonary veins,** which bring blood from the lungs to the left auricle. Each is a short, wide vein which will be seen to arise from the lung by several roots and go directly to the left auricle.

Exercise 12. Draw the dorsal aspect of the heart, together with the precaval and pulmonary veins and their branches, so far as these have been observed.

Follow the **postcaval vein** backward through the right lobe of the liver. Note the **hepatic veins** which enter it in the liver. Turn the right lobe over to the animal's left and note where the postcaval vein enters it from behind. Posterior to this point and near the anterior end of the kidneys, the postcaval is formed by the union of the two **iliac veins.**

Each iliac vein is formed in the mass of the anterior lobe of the kidney by the union of three veins, — the **renal portal,** the **anterior renal,** and the **femoral veins.** The last of these veins comes from the leg and will be seen approaching from the side and lying between the first and second lobes of the kidney. The renal portal has already been mentioned. It enters the hinder lobe of the kidney, after first receiving the **internal iliac vein** from behind, and passes forward imbedded in the kidney, giving off numerous small branches. It thus constitutes a portal vein, inasmuch as it distributes blood to the kidney instead of sending it directly to the heart. Instead of entirely breaking up, however, into small veins and capillaries, as does the renal

portal of the lower vertebrates, it soon begins to increase in size and joins the iliac. Consequently only a portion of the blood brought to the kidneys by the renal portal veins is distributed throughout them; the greater part probably goes directly to the iliacs and the heart.

The **anterior renal vein** is a large longitudinal vein which appears on the ventral surface of the kidney near the median line, imbedded in it.

Carefully follow the renal portal forward by picking away the substance of the kidney which surrounds it, until it joins the iliac vein. Follow the anterior renal and the femoral veins to the iliac. Follow the femoral vein into the leg and observe its branching.

Exercise 13. Draw a semidiagrammatic view of the postcaval vein and its branches, together with an outline of the organs in which the veins lie.

The arteries. Study the **dorsal aorta** and its branches. Remove the postcaval vein. The dorsal aorta branches off from the right side of the aorta almost immediately after that vessel leaves the heart; it forms an arch over the right side of the heart and the right bronchus, and reaches a dorsal position between the two lungs, when it runs backward to the hinder part of the abdominal cavity. Dissect it free and find its branches; cut the right bronchus near the lung; remove the thick peritoneal membrane which covers it.

The **dorsal aorta** gives off the following branches: several pairs of small costal arteries, the cœliac, anterior mesenteric, anterior renal, femoral, sciatic, posterior mesenteric, internal iliac, and caudal arteries.

The **cœliac artery** is a median vessel which leaves the dorsal aorta near the hinder end of the heart and runs back in the mesentery, sending off branches to the stomach, liver, pancreas, gizzard, and anterior part of the intestine. The **anterior mesenteric** is a large median artery which leaves the dorsal aorta a short distance back of the cœliac artery and runs back in the mesentery, sending branches to the greater part of the intestine. The

anterior renal arteries are a pair of small vessels which leave the dorsal aorta opposite the anterior lobes of the kidneys and go to them. The **femoral arteries** are a pair of vessels which leave the dorsal aorta behind the anterior renals and pass above the kidneys to the muscles of the thigh.

The **sciatic arteries** are a pair of large vessels which leave the dorsal aorta opposite the middle of the kidneys and pass between their middle and posterior lobes to the legs; each gives off a branch to the middle lobe and one to the posterior lobe of the kidney. Follow this artery into the leg. The median **posterior mesenteric artery** and the paired **internal iliac arteries** leave the aorta together near the hinder end of the kidneys, the former going to the rectum and cloaca, the latter to the muscles of the pelvis. The posterior end of the dorsal aorta is the **caudal artery**, which supplies the tail.

Exercise 14. Draw a semidiagrammatic sketch of the dorsal aorta and its branches, so far as these have been observed.

The internal structure of the heart. Remove the heart from the body. Identify the roots of the three caval veins which enter the right auricle; the right precaval and the postcaval will be quickly found; the root of the left precaval is attached to the dorsal wall of the auricles and lies across them. Identify the roots of the two pulmonary veins, which appear near together near the middle of the dorsal surface and enter the left auricle. Identify the short pulmonary artery and its right and left branches; identify the aorta, and the dorsal aorta together with the right and left innominate arteries which spring from it.

Cut across the wall of the right auricle; open the auricle, and remove the blood that will probably be found caked in it. Note the openings of the three caval veins; also the muscular fold projecting into the auricle, which forms a valve guarding the opening of the postcaval. Note the partition separating the right from the left auricle; also that separating the right auricle from the right ventricle. In the ventricle is a deep crescentic depression, the auriculo-ventricular opening, through which the blood goes into the ventricle.

Make a median longitudinal slit in the wall of the right ventricle and note the small extent of this ventricle. Note the **auriculo-ventricular opening** and the valve projecting into the ventricle, which prevents the flow of blood back into the auricle. Probe through the pulmonary arteries into the right ventricle; follow the probe with scissors and cut open the arteries. Note the three transversely placed **semilunar valves** which are situated at the base of the median pulmonary artery.

Open the left auricle by a transverse slit through its wall and remove the blood in it. Note that the pulmonary veins communicate with a partly separated chamber of the auricle. Observe the septum separating the auricle from the left ventricle and the round **auriculo-ventricular opening** in it. Open the left ventricle by a median longitudinal slit; note the thick walls, except at the apex, and the relatively small cavity with its longitudinal muscular ridges. The auriculo-ventricular or **mitral valve** will be seen to be formed of two flaps which are joined with the wall of the ventricle by cords, the **chordæ tendinæ**. Probe the aorta into the left ventricle and follow the probe with the scissors. Cut open the aorta and note the three pocketlike **semilunar valves** which extend across its base.

Make a cross section of the heart in the middle of the two ventricles and note the shape of them and the relative thickness of their walls.

Exercise 15. Draw a diagram showing the structure of the heart.

Exercise 16. Draw a diagram of the entire vascular system.

The respiratory system. This consists of the two lungs and the air sacs in connection with them, the two bronchi and the trachea by which the lungs are placed in communication with the outside world.

The **lungs** are spongy bodies lying close against the dorsal body wall and are covered ventrally by the **pleura,** which is a tough, thickened portion of the peritoneum. The lungs are relatively small in size and are held firmly in place between the pleura and the dorsal body wall, so that they are capable of very

little movement. They are not saclike, as in the lower land vertebrates, but spongy as in mammals, their interior being entirely filled with air cells. They are joined with the heart by the pulmonary veins and arteries, — the latter carrying venous blood away from them and the former arterial blood to them.

Entirely free the ventral surface of the lungs from the blood vessels and other structures which may still be attached to them, but do not injure the bronchi; dissect the pleura from both lungs, and the lungs away from the body wall. Note their intimate relation to this wall. Look for the openings into the air sacs.

Separate the œsophagus and crop from their attachments with the trachea and bronchi and turn them forward. Note the cartilaginous rings in the trachea and bronchi.

Exercise 17. Draw a sketch of the lungs and the trachea and bronchi.

The bird has two **larynges**, i.e., two regions in its respiratory system where the passage of air into and out of the lungs is controlled by a special mechanism. One of these is at the anterior end of the trachea and is homologous to the larynx of other vertebrates; the other is at its posterior end and is called the **syrinx**. It is this latter organ which produces the voice of the bird.

Study the structure of the syrinx. It consists of a chamber called the **tympanum** at the hinder end of the trachea which is formed at this place by the coalescence of the posterior tracheal and the anterior bronchial rings; in this chamber is a vibrating membrane called the **semilunar membrane** which produces the voice. On each lateral side of the trachea is the slender **broncho-tracheal muscle.**

Exercise 18. Draw the ventral aspect of the hinder end of the trachea and the forward ends of the bronchi, showing accurately the shape of the rings, on a scale of 3.

The **semilunar membrane** is a delicate median, vertical projection extending into the tympanum from the meeting point of the

medial walls of the bronchi. It is stiffened by a slender cartilage called the **pessulus** which lies in a dorsoventral position.

A number of small muscles are present on the trachea and the bronchi, which play a part in the production of the voice. These fall into two groups, — those which join the trachea with neighboring bones, and those which are confined to the trachea and bronchi. These muscles vary much in different birds. In the pigeon the largest are the **tracheo-sternal muscles**, — a V-shaped pair which join the trachea with the sternum and were seen when the great arteries issuing from the heart were studied, — and the **broncho-tracheal muscles**, the lateral pair which were seen on the sides of the trachea.

Open the tympanum by a lateral slit in the trachea and bronchus and note the semilunar membrane.

Exercise 19. Draw a semidiagrammatic sketch of the tympanum, showing the semilunar membrane.

Study the structure of the larynx. Dissect the anterior end of the trachea, with the larynx and tongue, from the body. The larynx is at the anterior end of the trachea; its opening into the pharynx is the **glottis**. Note the two long horns of the hyoid bone which lie on either side of the glottis. The opening of the glottis is bounded and supported on either side by the paired and partly ossified **arytenoid cartilages**. Remove the delicate muscles and the mucous membrane from the larynx and note the shape of the arytenoids.

Back of these cartilages are the **procricoid** and **cricoid cartilages**, which are modified tracheal rings. A thyroid cartilage is not present in birds. The cricoid cartilage, which is often wrongly called the thyroid, is a partly ossified ring, which is wide ventrally and incomplete on the dorsal side. Between its dorsal ends lies a small median plate, the procricoid, sometimes wrongly called the cricoid. The dorsal ends of the two arytenoids articulate with the procricoid; the ventral ends are free.

Exercise 20. Draw a lateral view of the larynx on a scale of 2 or 3.

Exercise 21. Draw an outline of the œsophagus with the crop.

The nervous system. This consists of (1) the **central nervous system**, which is made up of the brain and the spinal cord; (2) the **peripheral nervous system**, which includes the paired cranial and spinal nerves and the sympathetic nervous system; and (3) the **special sense organs.**

We shall first study the spinal nerves and the sympathetic nervous system. Remove what remains of the kidneys from the body, but be careful not to injure the nerves which lie beneath them.

The **spinal nerves** are those which place the spinal cord in communication with the muscles and skin of the trunk, neck, and limbs. They join the spinal cord in pairs, a pair lying between each two vertebræ in the intervertebral foramina. A single spinal nerve is formed of two roots, — a **dorsal root**, the fibers of which are sensory in function, and a **ventral root**, which is motor; on the former is a large swelling, the **spinal ganglion.** The two roots meet outside the intervertebral foramen, at the distal end of the ganglion.

Observe the spinal nerves of the trunk; they will be seen to be white cords lying on the dorsal wall of the body cavity between and parallel with the ribs. At the point where the neck joins the trunk, note the prominent **retractor muscles**, which connect the ventral and lateral surfaces of the former with the ventral surface of the thoracic vertebræ. Cut away these muscles; lying on them will be seen on each side a white cord, the **vagus nerve.** Lying opposite to these muscles at the base of the neck will be seen four very large spinal nerves which, together with a delicate branch from the next nerve back of them, form a network called the **brachial plexus.** From this plexus proceed the nerves which supply the wing and the muscles of the breast.

Thoroughly clean the plexus and follow the nerves which go to the wing. Note the spinal ganglion at the base of each nerve. The brachial plexus is formed of the eleventh to the fifteenth spinal nerves inclusive.

Exercise 22. Draw a diagrammatic view of the brachial plexus, showing accurately the arrangement of the nerves as observed.

The five spinal nerves following this plexus proceed straight laterally to the muscles of the trunk. The next two, which are the twenty-first and twenty-second, form the **lumbar plexus**; from it nerves go to the muscles of the thigh. The following four nerves, which are the twenty-third to the twenty-sixth inclusive, form the **sacral plexus**, from which the **great sciatic nerve** proceeds to the leg. These two plexuses are joined by a cross nerve. Thoroughly clean these nerves and follow the great sciatic nerve into the leg; observe its branching throughout the leg. Posterior to the sciatic plexus is the **plexus pudendus**, a simple union of the seven spinal nerves which extend obliquely back to the tail.

Exercise 23. Draw a diagram of these three plexuses and the nerves proceeding from them, so far as observed.

Study the spinal nerves of the neck in front of the brachial plexus. Ten pairs are present, of which all but the first two pairs may be seen issuing from among the muscles on the ventral side of the neck and passing dorsally.

The **sympathetic nervous system** consists of a pair of longitudinal nerve cords with paired ganglia which lie on either side of the spinal column between the head and the tail, in close connection with the spinal nerves. The cord is doubled on each side in the trunk, where it sends off numerous branches to the organs of the digestive and circulatory systems.

Find the main sympathetic nerves of the trunk. In the anterior and middle portions of the trunk the main nerve cords lie in the abdominal cavity along the base of the ribs. They consist here of two longitudinal nerves on each side which meet in the spinal ganglia, the sympathetic ganglia and the spinal ganglia being fused. Note carefully the relation of these two nerves to the ribs. At the base of the brachial plexus are two unusually large ganglia.

Follow the nerves and the ganglia into the posterior portion of the abdominal cavity. The ganglia will be seen to become rapidly smaller, and in the caudal region they are wanting. The double sympathetic nerve extends between the brachial and the

lumbar plexuses, posterior to which a single strand is present on each side of the spinal column.

A network of nerves starting from the longitudinal sympathetic nerves and ganglia in the anterior portion of the body cavity is present, from which the large **splanchnic nerve** springs. This nerve passes medially and joins the **solar plexus**, a network of nerves and ganglia surrounding the dorsal aorta and the base of the cœliac and anterior mesenteric arteries.

In the cervical region the sympathetic system consists of a single longitudinal nerve on each side, which lies in the vertebrarterial canal of the cervical vertebræ, together with the vertebral artery and the vertebral vein. It will not be seen.

Exercise 24. Draw a diagram of the sympathetic system, so far as observed.

The special sense organs; the olfactory organ. Entirely remove the skin and muscles from the head; remove also the eyelids, but do not injure the eyeballs. The **nasal capsules** consist of a pair of cavities, just in front of the eyes, separated from each other by the median **septum nasi.** They are in communication with the outside by the **nostrils** or **anterior nares,** and with the pharynx by the **posterior nares.**

Remove the outer wall of the right capsule completely and observe the interior. Note the slitlike posterior nares. In the interior are three swellings, the **turbinals,** which are lateral projections of the septum nasi. Of these, the two anterior are prominent, elongated structures; the third lies behind and somewhat above the middle turbinal at the hinder end of the nasal cavity. It is much smaller than the others, and the only one to which the olfactory nerve goes.

Exercise 25. Draw the nasal cavity.

The eye. Note the large size of the eye. Observe the front aspect of it. The outer layer is the **cornea,** which is transparent. It is a continuation of the black **sclerotic,** which is the outer layer of the back part of the eye; note the bony ring in this layer. Through the transparent cornea the **iris** and **pupil** will

be seen; the former is a yellow ring, the latter, the round opening into the interior of the eye. Lining the inner surface of the eyelids and forming the outer surface of the cornea is a transparent membrane called the **conjunctiva.**

Exercise 26. Draw these features.

The muscles of the eyeball. Cut away the bony ridge which surrounds the right eye and thoroughly expose the orbit, but without disturbing the eyeball or its muscles, or cutting through the thin skull into the brain. By pressing the eyeball backward, the insertions of two muscles, the **superior oblique** and the **inferior oblique,** are brought into view,—that of the former being on the medial surface of the eye and that of the latter on the antero-ventral surface. Both muscles have their origins on the anterior wall of the orbit. Beneath the inferior oblique and between it and the wall of the orbit will be found the **Harderian lachrymal gland,**—a small, fatlike body which moistens the nictitating membrane. The **lachrymal gland** is a very small white body at the hinder side of the eye, and may not be seen.

Just back of the insertion of the superior oblique is that of the **superior rectus muscle.** Pull the eye forward; the insertion of the **external rectus** will be seen on the posterior side of the eyeball. Cut the **superior oblique** at its insertion and pull the eye backward; beneath it will be seen the insertion of the **internal rectus muscle.** Cut all of these muscles at their insertions and pull the eyeball backward; the **inferior rectus** will be seen, which has its insertion on the inner surface of the eye. All of these rectus muscles have their origins in the posterior wall of the orbit.

Lift up the eyeball and cut the inferior rectus muscle and the optic nerve; remove it from the orbit. Without disturbing any of the structures of the orbit, observe the origins of the two oblique muscles in the anterior part of the orbit, and of the rectus muscles near the optic nerve. Lift up the inferior oblique and find the Harderian gland.

Two additional muscles are present which control the nictitating membrane,—the quadrate and the pyramidal muscles. These

lie close to the inner surface of the eyeball. The **quadrate** is a broad muscle the origin of which extends from the dorsal margin of the eyeball to the optic nerve. The **pyramidal** is a narrow triangular muscle which extends from the ventral margin to the optic nerve, where it meets the inner border of the quadrate.

Study the eye itself. The outer coating is the **sclerotic layer,** as we have already seen. Cut a small piece from the side of the eyeball near the bony ring which surrounds the cornea: the two other coatings of the eye — the **choroid layer** and the **retina** — will be seen. The former is the vascular layer; it contains the blood vessels which supply the eye; it also contains the pigment. The iris is the continuation of the choroid layer over the front of the eye; in it are circular and radial muscle fibers by the action of which the size of the pupil and the amount of light which enters the eye are controlled.

The **retina** is the soft inner coating of the eye. It is the essential sensory portion of it and the direct continuation of the optic nerve. Projecting through the retina at the back of the eye is a prominent pigmented and vascular ridged plate called the **pecten.** It belongs to the choroid layer and extends into the middle of the eye toward the lens, with which it is joined by a transparent ligament. Its function is unknown, although it may be to supply the lens with nutriment. It may be easily observed if a small piece be cut from the side of the eyeball opposite the first opening made.

Just back of the pupil and the iris is the **crystalline lens.** It is lenticular in shape and flatter on the outer than on the inner side. It is held in position by the **ciliary process,** to which it is attached by a delicate circular ligament; these structures lie just behind the iris on the inner surface of the bony ring which surrounds the cornea. Cut the eyeball in two by an equatorial incision and observe the inner surface. The ciliary process will be seen surrounding the lens and may be distinguished by its radiating fibers. The **ciliary muscles** are also present in the ciliary process; these muscles by their contraction slightly change the shape and position of the lens and thus enable it to focus light from objects at varying distances upon the retina.

Scrape away the ciliary process and note the bony ring surrounding the cornea; it is composed of a number of separate plates.

The interior of the eye is divided by the iris and the lens into two cavities,—an outer one between the cornea and the iris which contains the watery **aqueous humor**, and an inner one between the lens and the retina which contains the jellylike **vitreous humor.**

Exercise 27. Draw a diagram showing the structure of the eye, so far as observed.

The ear. The ear consists of the **inner ear** or membranous labyrinth, the **middle ear** or tympanic cavity, and the **external auditory meatus,** the passage leading from the middle ear to the outside. The inner ear is the essential organ of hearing to which the auditory nerve goes; the middle ear is joined with the pharynx by the **Eustachian tube** and is separated from the external auditory meatus by the **tympanic membrane** or eardrum.

Remove the lower jaw. Note back of the eye the external opening of the meatus. Cut away its sides on the right side of the head until the tympanic membrane, which lies at the inner end of the meatus, is exposed. This membrane is circular in shape and semitransparent. On its inner side it is joined with the **columella,** a rod of cartilage and bone which extends across the tympanic cavity from the tympanic membrane to the inner ear. Cut around the edge of this membrane, lift up an edge, and the columella will be seen within. At its inner end is an oval bone called the **stapes,** which covers an opening in the wall of the inner ear called the **fenestra ovalis.** The columella and stapes perform the same function as the three ear ossicles in the mammalian tympanic cavity; they convey the sound waves from the tympanic membrane to the inner ear.

The tympanic cavity and Eustachian tube are homologous to the first visceral cleft of fishes, which in the dogfish forms the spiracle.

The **inner ear.** The principal organs of the inner ear which can be seen in a dissection are the three **semicircular canals**; carefully shave away the bone in the auditory region and expose

them. Two of these canals are vertical in position, the anterior being the larger and more dorsal; the third canal has a horizontal position and lies lateral to the other two. These canals spring from a small sac called the **utriculus**, just beneath which is another small sac, the **sacculus**; projecting from the latter is the **lagena**, which corresponds to the cochlea of mammals.

Exercise 28. Draw a diagram showing the structures of the ear which have been observed.

The brain and the cranial nerves. Entirely remove the remaining skin and the muscles from the head and anterior end of the neck; remove the left eye. Beginning at its hinder side, cut away with scalpel and scissors the roof of the skull, exposing the dorsal surface of the brain. The skull is easily cut with a scalpel because of its spongy nature. It is very thin and the brain entirely fills the cavity; care must be taken, consequently, not to cut too deeply. Cut away also the upper half of the orbit and the side of the skull behind it.

The **brain** is made up of five divisions, of which two, the **cerebrum** and the **cerebellum**, project prominently dorsally and form almost its whole dorsal surface. The anterior division is the **cerebrum**, which is composed of the two large **hemispheres**; at their anterior ends are the two small **olfactory lobes**. Immediately behind the hemispheres and between them and the cerebellum is the delicate **pineal body** or **epiphysis**, which is a projection of the dorsal wall of the second division of the brain,— the **thalamencephalon**.

The third division, or **midbrain**, is composed dorsally of the **optic lobes**, which appear as a pair of spherical bodies at the sides of the brain between the ventral portions of the cerebrum and the cerebellum. This latter division is the fourth; it is marked by transverse grooves; posteriorly it overlaps the **medulla oblongata**, the fifth division, which is continuous with the spinal cord. At about the point where the spinal cord passes into the brain, the former turns sharply ventrally.

Exercise 29. Draw a view of the dorsal aspect of the brain.

Study the lateral aspect of the brain and the twelve pairs of **cranial nerves**, so far as these can be dissected. Entirely remove one side of the cranium, but preserve the ventral portion of the orbit, with the large nerves which cross it. The first pair of cranial nerves, the **olfactories**, are slender prolongations of the olfactory lobes; they pass to the nasal capsules. The second pair, the **optic nerves**, emerge from the **optic chiasma** on the ventral side of the second division of the brain and pass to the orbits. In order to see them, separate the floor of the cranial cavity from the cerebrum, beginning at its anterior end. The whole anterior end of the skull can be pressed down away from the brain so as to expose the ventral surface of the cerebrum and the optic nerves. The **optic tracts** will also be laid bare. They will be seen immediately back of the optic chiasma on each side and abutting on the optic lobes. The third nerve, the **oculomotor**, is a small nerve which arises just behind the infundibulum on each side and goes to the orbit.

The fourth nerve, the **trochlear** or **pathetic**, will be seen arising between the optic lobe and the cerebellum on the side of the brain and passing forward to the orbit. The fifth nerve, the **trigeminal**, is a large nerve which arises on the side of the medulla just beneath the optic lobe and passes forward to the large **Gasserian ganglion**. This structure lies in a depression in the wall of the socket, the skull and gives off three branches: (1) the **ophthalmic nerve**, which runs through the floor of the skull into the orbit; it passes along the upper portion of the orbit to a foramen in its anterior wall, where it enters the nasal capsule, through the of orbit entire length of which it runs; (2) the **maxillary nerve**, which enters the orbit and passes along its floor to the upper mandible; (3) the **mandibular nerve**, the largest of the three, which enters the orbit and divides into two branches, one of which supplies the temporal muscle while the other runs forward to the lower mandible.

The sixth nerve, the **abducens**, is short and small. It arises on the ventral surface of the medulla near the median line, nearly opposite the base of the trigeminal nerve, and passes through the floor of the skull to the orbit. It will be seen when the

ventral surface of the brain is studied. The seventh nerve, the **facial**, arises just back of the trigeminal on the lateral side of the medulla, and runs backward in two branches to the muscles at the base of the head. The eighth nerve, the **auditory**, is larger than the facial and arises immediately back of it.

The ninth nerve, the **glossopharyngeal**, which arises on the side of the medulla close to the auditory, and the tenth nerve, the **pneumogastric** or **vagus**, which arises close to the glossopharyngeal, pass out of the skull by the same foramen. Just outside of the foramen the glossopharyngeal merges into a large ganglion from which nerves are distributed to the muscles of the tongue and the base of the skull. The pneumogastric nerve passes straight back along the side of the neck to the body cavity, where it breaks into branches which supply the trachea, lungs, heart, stomach, and gizzard.

The eleventh nerve, the **spinal accessory**, is closely joined with the vagus. It arises on the side of the spinal cord by a number of roots, enters the cranial cavity through the foramen magnum, and passes out again, together with the vagus and glossopharyngeal, to the muscles of the neck. The twelfth cranial nerve, the **hypoglossal**, arises near the medial line on the ventral surface of the medulla; it leaves the skull by a foramen at its base and is distributed to the muscles of the neck.

Exercise 30. Draw a view of the lateral aspect of the brain and the cranial nerves, so far as they have been observed.

Study the ventral surface of the brain. Remove the brain from the head. Just behind the optic chiasma is a median projection of the thalamencephalon, the **infundibulum**; at its ventral end is the **pituitary body**, or **hypophysis**, which is usually torn off when the brain is removed. Back of the infundibulum are the two oculomotor nerves; they spring from the midbrain near the median line. The medulla oblongata extends from the midbrain to the spinal cord; near the median line at the anterior end of the medulla will be seen the abducens nerves.

Exercise 31. Draw a view of the ventral aspect of the brain.

Study the cavities of the brain. The brain is a hollow structure and contains a series of cavities which are a continuation of the central canal of the spinal cord. The cavities of the two hemispheres are called the **lateral ventricles**, or the **first** and **second ventricles**. Press the hemispheres slightly apart and cut through the thin inner and postero-medial wall of one of them into the ventricle. Remove a portion of the wall and observe the cavity. Note the large white mass on its ventral surface, which almost fills it; this is the **corpus striatum**. In the medial side of the posterior wall is the **foramen of Monro**, by which the lateral ventricles communicate with each other and with the **third ventricle**, which is in the thalamencephalon.

Remove the cerebellum by carefully cutting the **right** and **left peduncles**, which join it with the medulla on each side. Connecting the two optic lobes will be seen a bridge of white fibers called the **optic commissure**; in front of this is the roof of the third ventricle; behind it is the roof of the fourth ventricle. Remove the former and note the narrow space, the third ventricle, beneath, the thickened lateral walls of which are the **optic thalami**. Probe the ventricle and note its depth. Cut an opening in one of the optic lobes and note its ventricle. Connecting the third and the fourth ventricles is a median canal called the **aqueductus Sylvii**; the ventricle of the optic lobe joins it on each side. The **fourth ventricle** is broad and shallow.

Exercise 32. Draw a diagram showing the shape and position of the ventricles.

The muscular system. Kill a fresh animal. Make a midventral slit through the skin from the mouth to the anus, and skin the ventral surface of the body, including the wings and the legs. In order to avoid cutting the muscles and other organs beneath the skin, make this incision with scissors, lifting up the skin with forceps and then cutting it. Take special care not to cut the large thin-walled crop which lies in contact with the skin at the base of the neck, or the large blood vessels and nerves in the neck and the wings. Note the thinness and delicacy of the skin.

The **great pectoral muscles**, which depress the wings during flight, form a large part of the breast. They lie along the entire length of the keel of the breastbone and constitute the lateral and anterior surfaces of the trunk. A prominent tendon will be seen running through the midst of the muscle to the shoulder on each side; it passes over the shoulder and finds its insertion on the upper and outer surface of the humerus, — as will be seen when the muscle is dissected.

Posterior to the pectoral muscles are the **abdominal muscles**, which form the ventral and lateral body walls of the abdomen. In the midventral line, where the membranous tendons of the abdominal muscles of the right and left sides meet, is a prominent white line, the **linea alba**.

Make a transverse incision in the middle of the great pectoral, dividing it into an anterior and a posterior half. Be careful not to cut too deeply, as the lesser pectoral would be injured.

Note the large blood vessels in the muscle. Beneath the great pectoral lies the **lesser pectoral muscle**, which fills the angle between the keel and the body of the breastbone. Remove now that portion of the great pectoral back of this incision from the body, being careful not to cut the lesser pectoral, and note its attachment to the ventral portion of the keel and the lateral portions of the body of the breastbone. Dissect the anterior half of the great pectoral, from the incision forward, separating it from the lesser pectoral, the breastbone, and the clavicle (the wishbone), until the large tendon at its forward end is reached. Be careful in doing this not to cut or injure any of the bones. Follow the tendon to its insertion in the dorsal side of the humerus. A broad shoulder muscle, the anterior head of the biceps, covers this tendon.

Note the tendon which runs through the middle of the lesser pectoral muscle to the shoulder. Free the muscle from its attachment to the breastbone and the coracoid, which is the large bone joining the breastbone with the shoulder blade, and follow the tendon to its insertion in the dorsal side of the humerus. Be careful not to injure any of these bones while dissecting the muscles.

Test the action of both pectoral muscles; the great pectoral will be seen to depress the wing, and the lesser pectoral, to raise it.

The **abdominal muscles** are of much smaller extent in birds than in mammals, on account of the large size of the breast muscles. They consist of the right and left **external obliques,** which form the outer surface of the abdomen and whose fibers run diagonally; the **internal obliques,** which lie beneath the external obliques and whose fibers run at right angles to their fibers; the **transverse muscles,** which are the innermost and whose fibers run transversely; and the **rectus abdominis muscles,** which occupy the median area. All of these muscles are more or less rudimentary and tendinous, their fibers having disappeared and the membranous fasciæ and tendons alone being present in portions of them. The rectus abdominis has entirely lost the metamerism which characterizes it in amphibians and mammals. These muscles will not be dissected. Observe as many of these features as possible.

On the ventral side of the head note the **submandibular muscle,** the fibers of which run transversely across the throat; its median portion is tendinous.

In the proximal division of the **wing** (the upper arm) are the large **biceps muscle** on the anterior side and the large **triceps** on the posterior side; these muscles act as the chief flexor and extensor respectively of the forearm.

In the middle division (the forearm) the following muscles appear on the ventral surface, beginning with the anterior border: the **extensor radialis,** the **pronator brevis,** the **pronator longus,** the distal end only of which appears, the short **cubitocarpalis profundus,** the long **extensor carpi ulnaris,** and the large **flexor carpi ulnaris** which forms the posterior border. Determine, by following the tendons, which of these muscles extend and which flex the hand.

In the ventral surface of the proximal division of the **leg** (the thigh), beginning at the anterior border, are the large **sartorius muscle** which forms this border, the much smaller **ilio-tibialis,** a variable portion of the distal end of the **femoro-tibialis,** the

very broad **pubo-ischio-femoralis** which forms the middle portion of the thigh, the **semimembranosus**, and the **semitendinosus** which forms the posterior border of the thigh.

On the ventral surface of the middle division of the leg (the shank) are the **tibialis muscle**, which forms its anterior portion, and the **gastrocnemius**, which forms its posterior portion.

Determine so far as possible which of these leg muscles are extensors and which are flexors.

Exercise 33. Draw an outline of the ventral aspect of the animal and place in it those muscles which have been observed.

The skeletal system. This is made up of the **exoskeleton** and the **endoskeleton**. The exoskeleton is composed of certain special integumentary structures, — the feathers, the horny covering of the bill, and the scales and claws of the feet; the endoskeleton is the bony and cartilaginous framework of the body.

The exoskeleton. Three kinds of feathers are present, — the contour feathers, the down feathers, and the filoplumes or pin-feathers, — which have been described on page 166. Study the structure of a **contour feather**. It is made up of two portions, — the **quill**, the proximal, cylindrical portion which projects from the skin; and the **vane**, the distal flattened portion. The quill is hollow and has two openings, — one at the proximal end, the **inferior umbilicus**; and one at the base of the vane, the **superior umbilicus**.

The vane is composed of a central axis, the **shaft**, — the continuation of the quill, — which is solid and is square in cross section; the **barbs**, lateral outgrowths of the shaft; and the **barbules**, minute projections of the barbs. The barbules are usually provided with hooklike outgrowths which enable the overlapping barbules of contiguous barbs to take firm hold of one another and so convert the vane into an unbroken surface. At the base of the vane these hooks are absent.

Exercise 34. Draw a sketch of a contour feather showing the quill, vane, shaft, and barbs. Draw also one or two barbs, with their barbules and hooks, as seen under a microscope.

In **down feathers** there is either no shaft, — the barbs arising from the distal end of the quill, — or the shaft is very rudimentary; no hooks are present. In the **filoplumes** the barbs are either absent or are present in a rudimentary condition.

Exercise 35. Draw a down feather much enlarged. Draw a filoplume.

The **endoskeleton** is the inner framework of the body and is made up of bone and cartilage. It may be divided into (1) the **axial skeleton,** which includes the skull and the vertebral column, with the ribs and the sternum, and (2) the **appendicular skeleton,** which forms the framework of the extremities.

To prepare the internal skeleton for study, open the abdominal cavity, without injuring any of the bones, and remove all the viscera. The body should then be boiled a short time until the skin and muscles can be easily removed. Do not boil it so long that the skeleton falls apart. If the neck vertebræ show a tendency to become separated from one another, they had better be strung on a string. The head should be taken from the neck, and care taken not to lose the lower jaw or the hyoid apparatus which lies in the floor of the mouth and supports the tongue. Care must be taken also that the bones of the legs and wings, and of the uropygium, do not become separated.

Observe the general character of the skeleton. It is distinguished by great lightness, almost all the bones being hollow or spongy, instead of compact or filled with marrow. It is also distinguished by great rigidity, the bones having a decided tendency to ankylose.

The appendicular skeleton; the anterior extremities. These consist of the **pectoral girdle** and the **wings.** The pectoral or shoulder girdle is a strong structure which forms the connection between the skeleton of the wings and the trunk; during flight the body of the bird is supported in the air by the wings, and it is important that this connection be a strong and yet an elastic one. The girdle is composed of a right and a left half, which are joined ventrally by the sternum or breastbone.

Each half consists of three bones, — the **scapula**, the **clavicle**, and the **coracoid**. Of these bones the first named is dorsal in position; the other two are ventral, — the clavicle being anterior to the coracoid. The **glenoid cavity**, in which the humerus articulates, is situated at the meeting point of the scapula and the coracoid.

The **scapulæ** are a pair of elongated, flattened bones which lie along the spinal column, attached to it and to the ribs by means of muscles. The **coracoids** are a pair of thick bones which lie at right angles to the scapulæ and extend between them and the anterior end of the breastbone; they are firmly joined with both the scapulæ and the breastbone. This connection is a very important one, inasmuch as the greater part of the viscera lie in the concave dorsal surface of the breastbone. Note above the glenoid cavity the **foramen triosseum**, an opening formed by the meeting of a process from the scapula and one from the coracoid. The tendon of the lesser pectoral muscle passes through it.

The **clavicles** are ankylosed at their ventral ends and form the wishbone. Their dorsal ends articulate with the coracoids; their ankylosed ventral ends are joined by a ligament with the keel of the breastbone.

Exercise 36. Draw the pectoral girdle, with the anterior end of the breastbone.

The skeleton of the **wing** is made up of three divisions, — a proximal, a middle, and a distal division. The **proximal division** is composed of a single bone, — the **humerus**. The head of this bone is made up of the rounded articular surface, which fits into the glenoid cavity, and of a small anterior and a large posterior **tuberosity**. The anterior tuberosity is continuous with the prominent **deltoid ridge** in which is inserted the great pectoral muscle. In the great tuberosity is the **pneumatic foramen**, an opening into the hollow center of the bone. The distal end of the bone has two articular surfaces, an anterior one for the radius and a transverse, posterior one for the ulna.

The **middle division** is formed by the **radius** and **ulna**, of which the latter is somewhat longer and thicker than the former. At the proximal end of the ulna is the short **olecranon process**, which forms the elbow. Along the posterior border of the ulna is a row of small elevations which mark the position of the base of the secondary wing quills.

The **distal division** is made up of the wrist and the hand. The **carpal** or wrist bones are much modified, but two free bones being present, the **radial** and the **ulnar**, which are at the distal ends of the radius and ulna respectively.

The bones of the hand fall into two groups, the proximal **carpo-metacarpus** and the distal **digits**. The carpo-metacarpus is a large arched bone which is formed by the fusion of the distal carpal bones with the first, second, and third metacarpals. The digits are also three in number. The first, or thumb, is short and possesses free movement; it is situated at the base of the carpo-metacarpus and consists of two **phalanges**, the distal phalanx being very small. The second digit is the longest and has three phalanges; the third has a single phalanx.

Exercise 37. Draw the bones of the wing.

The posterior extremities. These consist of the **pelvic girdle** and the **legs**. The pelvic girdle is very large and is firmly ankylosed with fourteen or fifteen vertebræ, forming a solid support for the legs. The pelvic girdle is composed of a right and a left **innominate bone**, each of which has been formed by the fusion of three bones, — the **ilium**, **ischium**, and **pubis**. At the meeting point of these bones is the **acetabulum**, the depression in which the head of the femur articulates.

The **ilium** is the largest of the pelvic bones. It is a large, flat bone, dorsal in position, and is fused along its entire length with the vertebral column; it is divided into two parts, an anterior and a posterior, the former of which is concave and the latter convex dorsally.

The **ischium** and the **pubis** are both ventral to the acetabulum, the latter being anterior and ventral to the former. The ischium is larger than the pubis and is separated from the ilium at its

forward end by a large opening, the **iliosciatic foramen.** The pubis is long and slender and is separated from the ischium by the long and narrow **obturator foramen.**

Exercise 38. Draw the dorsal and lateral aspect of the innominate bone.

The skeleton of the **leg** is made up of three divisions, — a proximal, a middle, and a distal division. The **proximal division** is composed of a single bone, the **femur**, which articulates in the acetabulum. On the outer side of the head of the bone is a ridge, the **great trochanter.** The **patella** — a small bone which is present in the tendons passing over the knee — lies in front of the distal or lower end of the femur; it is usually lost when the leg is cleaned.

The **middle division** is composed of two bones, the **tibio-tarsus** and the **fibula**; the first is a large bone which has been formed by the fusion of the **tibia** with the proximal **tarsal** or ankle bones; the second is a slender bone which is often fused with the first.

The **distal division** is composed of the bones of the foot. They fall into two groups, — a vertical shaft, the **tarso-metatarsus**, and the toes or **digits.** The tarso-metatarsus is formed by the fusion of the distal tarsal or ankle bones with the second, third, and fourth metatarsal bones. The boundaries of the three metatarsals are easily distinguished. No free tarsal bones are present, — the proximal row being fused with the tibia, as just stated, to form the tibio-tarsus; the distal row, with the metatarsals to form the tarso-metatarsus.

Four **digits** are present. The first digit, which corresponds to the big toe, projects backward and is raised above the ground. It is composed of the first **metatarsal** bone, which is very small, and two **phalanges.** The second digit is the innermost of the three projecting forward; it has three phalanges. The third digit has four phalanges and the fourth digit has five.

Exercise 39. Draw an outline of the bones of the leg and foot.

The axial skeleton. This is composed of the skull and the vertebral column, with the ribs and the sternum. The **vertebral**

column consists of a succession of vertebræ which may be divided into the following regions: the cervical, thoracic, lumbar, sacral, and caudal. The boundaries separating these regions in birds are not definite but are more or less arbitrary. The vertebræ of all except the cervical region show a marked tendency to fuse together; the cervical region, on the other hand, is characterized by great flexibility.

Each **vertebra** is composed essentially of the following parts: the **centrum**, which forms its body; the **neural arch**, which rises from the dorsal surface of the centrum and is composed of the two **neural processes** and the **neural spine**; the paired **transverse processes**, which project laterally or ventrolaterally from its sides.

The **cervical vertebræ** are fourteen in number. Study these and note carefully their variations of structure. The centrum is elongated. Its ends are saddle-shaped, the anterior end being convex dorsoventrally and concave laterally, while the posterior end is concave dorsoventrally and convex laterally. The transverse process projects back from the anterior portion of the centrum on each side, and is prolonged into a short spine. At the base of the process is a prominent foramen, and the series of these foramina in the successive cervical vertebræ form the **vertebrarterial canal**, in which the vertebral artery and vein and the sympathetic nerve lie. The transverse process and its spine are not strictly homologous to the transverse processes of the other vertebræ, but are equivalent to a rib plus the process. The foramen lies between the head of the rib and the process. Besides these rudimentary cervical ribs two pairs of free ribs are present on the last two cervical vertebræ; they do not reach the sternum.

Projecting from both the anterior and the posterior end of the neural arches are two small processes by which the successive vertebræ articulate with one another. These are called the **prezygapophyses** and **postzygapophyses**, the former projecting from the anterior end of the vertebra and articulating with the latter on the vertebra in front of it.

The first two cervical vertebræ are called the atlas and the axis; they support the skull and differ in structure from the

others. The **atlas** is a ring-shaped bone in which the centrum and the neural spine are absent, and the transverse processes are broad, winglike projections. On its anterior face is a median groove; into this fits the condyle by which the skull articulates with the spinal column. On its posterior face is also a median groove in which lies the odontoid process of the axis. These grooves are bounded dorsally by a transverse ligament which separates them from the neural canal.

The **axis** is an elongated vertebra, projecting from the anterior end of which is the cylindrical **odontoid process**; this process is equivalent to the centrum of the atlas.

Exercise 40. Draw the lateral aspect of the sixth cervical vertebra on a scale of 2; draw the anterior aspect.

Exercise 41. Draw the anterior aspect of the atlas on a scale of 2.

Exercise 42. Draw the lateral aspect of the atlas and axis on a scale of 2.

The **thoracic vertebræ** are five in number, being those which are joined with the sternum by ribs. They are all fused together, and with the lumbar vertebræ. The posterior thoracic vertebra is also fused with the pelvis.

The three **lumbar vertebræ**, the four **sacral vertebræ**, and the anterior six **caudal vertebræ** are all fused with one another and with the pelvis. These vertebræ, together with the fifth thoracic vertebra, form what is called the **synsacrum**.

Note carefully the character of these fused vertebræ, especially of their transverse processes. Note the intervertebral foramina through which the spinal nerves pass.

The free **caudal vertebræ** are six in number. The spinal column ends posteriorly with the **pygostyle**, an irregular bone formed by the fusion of several vertebræ.

The ribs. The first two ribs articulate with the last two cervical vertebræ and do not reach the sternum. Each has two articular surfaces,—the **head** or **capitulum**, which articulates with the centrum; and the **tuberculum**, which articulates with the transverse process. The posterior five ribs articulate with the

thoracic vertebræ and also with the sternum. Each thoracic rib has two portions, — a dorsal vertebral portion and a ventral sternal portion, which articulate with each other. Projecting backward from the vertebral portions of all the ribs except the first and the last is the prominent **uncinate process.**

The **sternum,** or **breastbone,** is a large flat bone which extends far back of the ribs and covers the ventral side of the breast and a large part of the abdomen. On its ventral surface is the **keel,** which projects ventrally in the median plane. Inasmuch as the principal muscles of flight have their origin in the sternum, the size of these muscles and consequently the powers of flight are directly correlated with the size of the sternum. Birds which do not fly, as the ostrich, have a very small sternum, on which there is often no keel. Projecting from the lateral edge of the sternum on each side near its middle is the prominent **middle xiphoid process.** Behind this is a deep notch, and behind that, the small **external xiphoid process** which fuses posteriorly with the body of the sternum, inclosing a small opening. In front of the middle xiphoid processes are the articular surfaces of the ribs, and at the anterior end of the sternum those of the coracoid bones.

Exercise 43. Draw a lateral view of the thorax, showing the thoracic vertebræ, the ribs, and the sternum.

Exercise 44. Draw a ventral view of the sternum.

The skull. The skull is made up of two portions,—the **cranium** and the **visceral skeleton.** The former protects the brain and the organs of special sense; the latter forms the framework of the face, the beak, and the tongue.

The cranium — which forms the entire top and back part of the skull — is characterized by the great lightness of the bones composing it and their tendency to become ankylosed. They are not compact but are spongy; the air cells in them can be seen through the outer wall by holding the cranium up to the light. In an old bird ankylosis has gone on so far that the sutures marking the boundaries of the bones have largely disappeared; in a young bird, however, they are still present.

The visceral skeleton, which forms the ventral part of the skull, is also characterized by the lightness and delicacy of its bones and the absence of teeth. It is much less firmly joined with the cranium than in mammals. Care must be taken to preserve the lower jaw and the hyoid apparatus.

Study the **posterior surface** of the skull. The large circular **foramen magnum** is seen here, through which the spinal cord joins the brain. Beneath it is the **occipital condyle**, by which the skull articulates with the atlas; note carefully its shape. The hinder end of the skull is formed by four bones in the young bird,—the **basioccipital** — beneath and in front of the foramen magnum, the paired **exoccipitals** at the sides, and the **supraoccipital** dorsal to it.

A more or less prominent semicircular ridge, called the **lambdoidal crest**, in which certain muscles of the neck are inserted, runs across the hinder end of the skull, separating the occipital from the parietal region; at each end of this crest is the **tympanic cavity.**

Study the **dorsal surface** of the skull. Its roof is formed by three pairs of large membrane bones, the parietals, frontals, and nasals. The **parietals** are the hindermost, — the suture between them and the frontals being in the young bird at the hinder border of the orbit. The **frontals** form the portion of the roof between the orbits, — the suture between them and the nasals being at the forward border of the orbits. The **nasals** extend forward from the anterior end of the frontals and form the base of the beak; each one of them sends a long process along each side of one of the nostrils.

In front of the nasals are the **premaxillæ**, which form the anterior portion of the beak and belong to the visceral skeleton. Each premaxilla is composed of three parts, which meet in the tip of the beak, — the **nasal process** and **maxillary process**, which lie on the inner and outer side of the nasal opening respectively, and the small **palatine process**, which forms the anterior part of the roof of the mouth.

Exercise 45. Draw the posterior aspect of the skull on a scale of 2.

Exercise 46. Draw the dorsal aspect of the skull.

Study the **lateral surface** of the skull. Note the very large orbit. In the hinder part of the skull will be seen the **lambdoidal ridge** and the **tympanic cavity**. Between this cavity and the parietal on each side is the large **squamosal** bone, which forms the posterior border of the orbit.

The **tympanic cavity** is a circular depression, within the margin of which is the **tympanic membrane** or eardrum. On the inner wall of the cavity are two foramina, the **fenestra ovalis** and the **fenestra rotunda**, the former of which is dorsal to the latter and is closed by the **stapes**, the innermost of the two ear ossicles. The stapes articulates with the **columella**, — the outermost and larger of these ossicles, — which is a rod of bone and cartilage extending to the inner surface of the tympanic membrane. At the anterior end of the tympanic cavity is the opening of the **Eustachian tube**, which places the cavity in communication with the pharynx. Probe it with a bristle.

Projecting forward from the anterior border of the squamosal are two short processes, the more dorsal being the **zygomatic process**; the more ventral articulates with a thick, irregular bone, the **quadrate**. This bone is the **suspensorium** of the jaws on each side, i.e., it connects them with the cranium; both upper and lower jaws articulate with the ventral and anterior surfaces of it, as will be seen later. The quadrates are not tightly joined with the remainder of the skull, but articulate freely with it. The jaws are thus joined with the cranium by a double articulation on each side.

In front of and above the tympanic cavity and medial to the quadrate bone is the **trigeminal foramen**, through which the trigeminal nerve passes.

The orbit is a very large cavity which is bounded behind by the **squamosal** and the **alisphenoid**, the latter bone being in front of the former; above, it is bounded by the large **frontal bone**, — which forms the whole roof of the skull between the orbits, — and in front by the **frontal** and the **lachrymal**, the latter bone forming its anterior border. The inner wall of the two orbits, the **interorbital septum**, is formed by the fusion of the **presphenoid** and **orbitosphenoid** posteriorly, the elongated **rostrum** ventrally,

and the **mesethmoid** anteriorly. The ventral wall of the orbit is almost entirely lacking.

In the hinder part of the orbit is the large optic foramen through which the optic nerve enters it; just back of this are the foramina of the oculomotor and the trochlear nerves.

Anterior to the frontals are the **nasal** and **premaxillary bones,** which have been already described.

Extending back on each side from the premaxilla to the quadrate is a slender bar which is composed of three bones fused together, the hinder part being the **quadratojugal,** the middle part the **jugal,** and the small forward end the **maxillary.** Medial to this bar the quadrate is joined with the premaxilla by a second row of bones consisting of the **pterygoid** and the **palatine,** the former articulating with the quadrate, the latter with the premaxilla.

The **lower jaw,** or **mandible,** is a bony arch which is composed of five pairs of bones fused together. The hinder end on each side is formed by the **articular bone,** which articulates with the quadrate. The articular is an ossification of the proximal end of Meckel's cartilage, which in the embryo forms the whole of the lower jaw. This cartilage persists in the adult but is covered with membrane bones. These are the **dentary,** the largest of the bones of the mandible, which forms the anterior half of each side; the **supra-angular,** which forms the dorsal portion of the posterior half; and the **angular,** which is a small bone on the inner side of the posterior portion.

Exercise 47. Draw the lateral aspect of the skull on a scale of 2.

Study the **ventral surface** of the skull after the lower jaw has been removed. At the hinder end is the **basioccipital** bearing the condyle. Covering the base of the cranium between the tympanic cavities is a large membrane bone, the **basitemporal,** which represents the posterior portion of the parasphenoid of lower vertebrates. This bone entirely covers the basisphenoid and, in old birds, is fused with it. In front of it is an elongated membrane bone, the **rostrum,** which represents the anterior portion of the parasphenoid. It covers and is fused with the presphenoid, mesethmoid, and the orbitosphenoids.

A number of **foramina** pierce the base of the skull. On each side of the occipital condyle is the foramen of the hypoglossal nerve, and lateral to it is the common foramen of the glosso-pharyngeal, vagus, and spinal accessory nerves. In front of these is the foramen of the facial nerve.

The **upper jaw** will be seen to be composed of two paired rows of bones, — an outer and an inner one, — which meet, on each side, at the quadrate bone posteriorly and at the premaxilla anteriorly. The outer row is composed of the maxillæ, the jugals, and the quadratojugals; the inner row, of the pterygoids and the palatines. The pterygoid is a short bone which articulates with the inner surface of the quadrate and with the rostrum. The palatine is a long bone which extends forward from the pterygoid, its hinder portion being broad, its anterior portion slender. Note carefully the relation of all these bones to one another.

Exercise 48. Draw the ventral aspect on a scale of 2, and carefully label all these characters.

The bones of the **cranium**, which have just been studied, fall into two categories, — those forming the cranium proper or brain case, and those forming the special sense capsules. The following bones belong to the **cranium proper** or brain case: the occipitals, the sphenoids, and the ethmoid, which are cartilage bones; and the parietals, frontals, basitemporal, and rostrum, which are membrane bones. The **special sense capsules** are three in number. The **auditory capsule** is formed by three cartilage bones, — the proötic, opisthotic, and epiotic, — all of which in the adult bird are fused with other bones. The proötic, in which the largest part of the auditory capsule is lodged, is fused with the squamosal, a large membrane bone which forms a part of the wall of the brain case. The epiotic fuses with the supraoccipital, and the opisthotic with the exoccipital. The **optic capsule** does not ossify, but the lachrymal — a membrane bone — develops in connection with it and forms a part of the anterior wall of the orbit. Besides these, a row of small membrane bones called the sclerotic plates appear in the sclera around the cornea. The

nasal capsule is formed by the mesethmoid, the nasals, and the vomer.

The remaining bones of the skull, which form the upper and lower jaws, the suspensorium, and the hyoid apparatus, belong to the visceral skeleton.

Study the **hyoid apparatus.** It is composed of a jointed median **body**, and two pairs of slender projections called the **horns** or **cornua.** The body is composed of three pieces. The anterior piece — the **basihyal** — is the largest and is shaped like an arrow-head. It is partly cartilaginous and partly bony, and from its hinder end extends a pair of short projections, — the **anterior cornua.** The middle piece is of bone, and from its hinder end extends a pair of long, slender projections, — the **posterior cornua,** — which are composed principally of bone and are jointed. The posterior piece is composed of bone and cartilage.

Exercise 49. Draw the hyoid apparatus.

CHAPTER V

MAMMALS

THE CAT

Two or three specimens will be needed for a complete dissection of the cat, — one for the muscles and skeleton, and one or two for the remaining organs. They should be killed with chloroform or ether, as needed, and preserved in cold storage or in formalin. If the weather be not too hot, it is an excellent plan to pin the skin tightly over the body and keep it in a cool place when it is not being dissected. As soon as it begins to smell it should be completely skinned, with the exception of the feet and head, and preserved in a solution of half a per cent or one per cent formalin. The body must always be completely covered by the fluid, and the latter must be changed as often as it becomes stale. A stronger solution of formalin than that mentioned tends to render the muscles and other organs hard and leathery.

It is also a good plan, although not necessary to the success of the dissection, to inject the arteries of the animal first with a five per cent solution of formalin, which preserves the internal organs and hardens the brain, and then with a red injection mass, in order to make the arteries easier to study. It is best to do this through the femoral artery near the base of the hind leg. The veins can also be injected, if desired, at the same time, with a blue injection mass through the femoral vein; the veins, however, can be easily studied without injection. Skin the inner surface of the leg from the trunk to the knee. The femoral artery and vein will be seen lying alongside of each other in the middle of the thigh, very near the surface; the vein is the larger of the two, and is filled with blood, while the artery is a pale pink in color.

If this be not done, it will be necessary, in order that the brain may be studied when the time comes, to cut off the head of a fresh cat and, after sawing off the top of the skull, to place it in a five per cent solution of formalin, or, what is better, a solution consisting of one part of five per cent formalin and three parts ninety-five per cent alcohol, and to leave it there until the brain is thoroughly hardened and is needed for study. In removing the top of the skull, care must be taken not to saw into the brain, and also to remove the transverse, bony partition between the cerebrum and the cerebellum without injuring either.

Study the external characters of the animal. Just as a bird may be told by its feathers, so the most distinguishing feature of the mammal is its hair; all mammals have hair, and only mammals have it. It is a highly specialized epidermal structure, whose principal function is the retention of the bodily heat of the animal. The warm air between the hairs is not easily removed; radiation is thus checked and the animal keeps warm. It is largely due to the development of hair that mammals have become animals with a constant temperature, or warm-blooded animals. In cold-blooded animals the temperature is in a high degree inconstant, varying sometimes 100° Fahr. at different times, — being approximately that of the surrounding air or water.

Observe the arrangement of the hair on the body. Almost the entire body is covered, only the tip of the nose, the walking pads of the feet, and the tips of the nipples being bare. Note the difference in the texture of the hair on different parts of the body. The most highly specialized hairs are the **whiskers**, or **vibrissæ**, on the upper lip, the sides of the cheeks, and above the eyes. These are tactile organs and are an important assistance to a nocturnal animal.

Observe the color of the animal and note if the color patches are bilaterally symmetrical. The domestic cat is probably descended from the Egyptian wild-cat, *Felis maniculata*, the color of which is mottled gray, very much like that which is so common among domestic cats; domestication, however, has resulted in a wide range of variation in color, from pure white to pure

black. Observe the difference in color between different regions of the animal's body, — the back and the belly, the head and the trunk, the inner and the outer sides of the leg, etc.

Observe the general form and shape of the body. The trunk is a laterally compressed, cylindrical structure; the head is large and compact, the neck short, and the tail long. The rather short legs with their sharp retractile claws, the lithe, muscular body, the strong jaws and large teeth fit the animal for a predaceous life in the woods and fields.

The **body** may be divided into four regions, — the **head, neck, trunk,** and **tail**; the trunk may be further divided into the thoracic, lumbar, and sacral subregions.

The head. This body region articulates with the vertebral column by two occipital condyles. It is very solid and compact, all of the bones being closely knit together, and the upper jaw being firmly joined with the cranium. This feature is correlated with the structure of the teeth. Instead of these being all alike in form, as is the case among most of the lower vertebrates, and being of use principally in seizing the food, they are specialized to perform a variety of functions, the front teeth to seize the food and the back teeth to chew it.

The **mouth** is large and is guarded by upper and lower lips. The **nostrils** are a pair of large openings at the end of the projecting **nose.** The **eyes** are large, and each is protected by three eyelids, — the **upper lid,** the **lower lid,** and the **nictitating membrane,** or third eyelid. This third lid is an opaque membrane at the inner corner of the eye, which moves across it. Take hold of it with forceps and pull it across the eye. There are no eyelashes, the whole surface of the lids being covered with hair. A pair of large external **ears** is present.

The neck. The neck is short and strong. In land mammals the length of the neck is usually correlated with the length of the fore legs;—an animal with long legs has a long neck. This is because the mouth is the usual organ of prehension and the animals seize their food on or near the ground. The length of the neck and head must be such that the mouth is brought to the ground when the head is bent down.

The neck in all land vertebrates is a flexible body division, its principal function being to give the head a wide range of movement; this is important, inasmuch as the head bears, besides the organs of prehension, the special sense organs, which are the principal organs of orientation.

The trunk. This region is made up of the thoracic, lumbar, and sacral subregions, — the first and third of which are rigid regions and support the two pairs of extremities, while the second is a flexible one.

The **thoracic subregion** is the animal's chest; it contains the heart and lungs, which are inclosed in a bony case composed of the spinal column, the ribs, and the breastbone. It also contains the pectoral girdle, by means of which the skeleton of the fore limbs is joined with the trunk. This girdle consists principally of the two large shoulder blades or scapulæ, which are imbedded in the muscles of the back and sides. Two pairs of nipples are present on the ventral side of this region.

The **lumbar subregion** is the animal's abdomen; it contains the bulk of the important viscera. Its walls are strengthened dorsally by the spinal column, the transverse processes of which are here very long; laterally and ventrally they have no bony support. This subregion forms the pivot of the body; it is where the body bends when the direction of movement is changed. It follows, consequently, that an active and agile animal like the cat has a relatively large lumbar region. In a two-legged vertebrate, like the bird, the body does not bend when the direction of movement is changed, and the lumbar region is not functional in this way. Three pairs of nipples are present on the ventral side of this region in the cat.

The **sacral subregion** is the most rigid portion of the body except the head. In it lie the hinder portions of the digestive and urogenital organs, together with the anus and the urogenital openings, the former of which is dorsal to the latter. It also contains the pelvic girdle, by means of which the skeleton of the hind limbs is joined with the trunk. The forward motion of the animal is accomplished largely by means of the hind limbs, the front limbs being of use principally in supporting

the anterior end of the body and in changing the direction of movement. The connection of the pelvic girdle with the trunk is consequently much firmer than that of the pectoral girdle. The pelvic girdle forms a complete arch, the bones of which are immovably joined with one another and also with the spinal column by sutures.

The tail. The caudal region is the most flexible of all. It is also of the least apparent importance to the animal, and varies much in size in different cats. In Manx cats it may be entirely absent; in Angora cats it is very long and bushy. In water vertebrates the tail is a very important part of the body, since it is the principal organ of locomotion. Land vertebrates have inherited it from their aquatic ancestors, and as it is no longer needed for locomotion it is put to a variety of uses, — and may even be absent altogether.

The appendages. Two pairs of appendages are present, — the **fore** and **hind limbs.** Each is made up of three divisions, a **proximal,** a **middle,** and a **distal division.** In the fore limb these are the upper arm, the forearm, and the wrist and hand respectively. The hand has five digits, which are provided with retractile claws. The first digit, or thumb, is above the others and is more or less rudimentary. Note the walking pads on the sole of the foot; on the opposite side to the thumb is a small pad which is over the pisiform bone of the wrist. Identify the three divisions of the leg, — also the shoulder joint and the elbow.

In the hind limb the proximal division is the thigh, the middle division is the shank, and the distal division is the ankle and foot, the latter having four digits which are provided with retractile claws. Note the walking pads on the foot; also the heel, which projects back from the upper end of the ankle. Identify the three divisions of the leg; also the hip joint and the knee.

Observe the position of the fore and hind legs with reference to the trunk and to each other. The elbow and the knee will be seen to project in opposite directions, the elbow being directed backward and the knee forward. The primitive positions of the vertebrate leg, as illustrated in some of the lower amphibians,

have already been spoken of (see page 67). In most of the land vertebrates a further important change in the position of the limbs takes place, which consists in the rotation of the whole limb about 90°. The fore limb rotates backward and the hind limb forward, so that the elbow and the knee come to point toward each other instead of in the same direction.

In the hind limb the preaxial or anterior side, on which is the big toe, is turned inward toward the body by this movement, and the foot comes to be directed forward.

The fore limb, in the cat and in most other mammals, undergoes a further change. The preaxial side of it with the thumb, by the rotation just mentioned, would be turned outward, away from the body; and the fore foot, as well as the proximal division of the leg, would be directed backward. The lower end of the preaxial side, however, rotates again around to the inner side of the leg, so that in its final position it is on the side toward the body and the foot is directed forward.

It is in this way that the big toe and the thumb both come to be on the side of the leg toward the body, and both feet to be directed forward, notwithstanding the fact that the knee and the elbow are directed in opposite directions.

Exercise 1. Draw an outline of a side view of the cat, and label the various parts of the body.

Exercise 2. Draw a dorsal view of the head.

Exercise 3. Draw a front view of the head, showing the nostrils and mouth.

Exercise 4. Draw a semidiagrammatic sketch of the inner surface of the fore foot and the hind foot, showing the toes, claws, and walking pads. Label all.

The internal organs. Place the animal on its back on a dissecting board and fasten each foot firmly to the board by means of a nail or strong pin, or a cord. Make an incision through the skin in the midventral line the entire length of the body. Separate the skin from the fat and muscles beneath it for a short

distance on each side of the incision; if the animal is very fat, remove the fat present here. Make, now, a midventral incision through the body wall from the pelvic girdle, which may be felt through the muscles at the hinder end of the trunk, to the breastbone, which may also be felt a short distance back of the fore legs; make also a short transverse cut from the middle of this incision on each side.

The cavity of the abdomen will thus be opened. The red lobes of the **liver** with the green **gall bladder**, and the **stomach** will be seen at the forward end of this cavity, the latter organ lying at the left of the liver. Back of them is an extensive membrane, the fat-filled **great omentum**, covering the intestine. At the hinder end of the cavity will be seen the **urinary bladder**, which is joined with the ventral body wall by a thin mesentery. The forward ends of the stomach and liver rest against a transverse muscular partition, — the **diaphragm**, — which forms the forward wall of the abdominal cavity.

Make now with scissors a longitudinal incision along each side of the breastbone through the body wall to the forward end of the trunk. Cut the diaphragm where it joins the ventral body wall on each side. Lift up the hinder end of the breastbone and, without further cutting or disturbing anything, look into the thoracic cavity, which is thus opened.

It will be seen, in the first place, that the entire **body cavity** is made up of these two divisions, — the **abdominal cavity** and the **thoracic cavity**, — which are separated by the diaphragm.

The **thoracic cavity** contains the **lungs**, the **heart** and the great vessels which enter and leave it, the posterior portion of the **œsophagus** and the **trachea**, and the **thymus**. A thin membrane called the **pleura** lines its inner surface. The space within the thorax is not, however, a continuous one, but is subdivided into several distinct compartments. The pleura forms two closed sacs, called the **pleural sacs**, which occupy the right and left sides of the thoracic cavity. Within each of these sacs one of the lungs projects, covered by a fold of the pleura.

The medial walls of the pleural sacs do not extend to the median plane of the body, but inclose between themselves a

large space called the **mediastinum**, which occupies the medial area of the thoracic cavity. Within this space lie the median, unpaired organs of the thorax, — the heart and its great vessels, the œsophagus, the trachea, and the thymus.

By lifting up the hinder end of the breastbone a view of the thoracic cavity will be obtained. The large **heart** will be seen inclosed in the membranous **pericardium**, in which much fat is often imbedded. Dorsal to the heart are two thin membranes passing diagonally to the right and left, to the dorsal body wall. These are the medial walls of the pleural sacs, and the space between them is the mediastinum, in which the heart lies. Ventral to the heart the walls of the mediastinum are much nearer together than dorsally, and appear as a single membrane which joins the pericardium with the body wall in the midventral plane. Do not disturb any of these organs.

Exercise 5. Draw a figure representing a diagrammatic cross section through the thoracic cavity, showing the relative positions of the two pleural sacs, the mediastinum, the pericardium, and the lungs.

The **abdominal cavity** contains the greater part of the digestive organs, the reproductive organs, and other important viscera. It is lined by a thin membrane called the **peritoneum**, which forms a sac inclosing nearly the entire abdominal space. Just as the pleural sacs are closed sacs, so the peritoneal sac, in the male animal, is a closed one, while in the female it is closed except that the reproductive system furnishes a pair of openings to the exterior through which ova and young find an exit. Also, just as the lungs and other organs project into the pleural sacs, covered, however, by folds of their walls, so the various organs of the abdominal cavity project into it, carrying folds of the peritoneal wall with them. Thus all of the abdominal organs will be found attached to the abdominal wall by these peritoneal folds, which are called **mesenteries**, in the broad use of the term.

Immediately back of the diaphragm are the stomach and the liver, as we have already seen. The mesentery of the latter is

called the **suspensory ligament**; it is the median, vertical membrane, which appears between the right and the left halves of the liver and joins it with the diaphragm. Appearing on the right side of the liver is the green gall bladder. The **great omentum**, which covers the viscera back of the liver, is the mesentery of the stomach. It arises from the peritoneum in the middorsal line between the diaphragm and the kidneys, and, instead of passing directly to the stomach, goes first posteriorly to the region of the pelvis, and then, turning on itself, passes forward to the greater curvature of the stomach. Thus it will be seen to form a great sac, the **omental sac**, which lies ventral to almost the entire abdominal viscera.

The abdominal cavity in mammals is not the equivalent of the entire abdominal cavity of other vertebrates, but only of the middle and hinder portions of it. In other vertebrates no diaphragm and consequently no thoracic cavity is present, the body cavity being divided into the abdominal and pericardial cavities. In mammals the pericardial cavity with the heart is contained in the thoracic cavity.

Exercise 6. Draw a semidiagrammatic sketch of the abdominal cavity, in an outline of the body, together with the organs which appear in a ventral view. Carefully label all of them.

The digestive system. This is made up of the mouth, pharynx, œsophagus, stomach, small intestine, large intestine, the salivary glands, liver, and pancreas. Lift up the great omentum and cut it away, being careful not to injure the viscera with which it is joined. The flat dark-red **spleen** will be seen in the omentum on the left side of the body close to the **stomach**, also the large **splenic veins** and **arteries**. Close to the dorsal surface of the stomach and in contact with the spleen is a portion of the long, flat, light-red **pancreas**. Do not cut or remove any of these organs.

The stomach and intestine are thus fully exposed. Observe carefully the form and position of the **stomach**. Note where the œsophagus comes through the diaphragm and joins it. The

stomach has two distinct divisions, — the broad anterior portion which lies directly back of the diaphragm on the left side of the body, and the narrow posterior portion which bends sharply forward and lies near the median plane. Its anterior end, where the œsophagus joins it, is called the **cardiac end**; the posterior end, where it passes into the intestine, is called the **pyloric end.** Its convex left side is called the **greater curvature,** and the concave right side, the **lesser curvature.** The portion of the greater curvature which extends farthest to the left is called the **fundus** of the stomach.

Study the course of the **intestine.** This portion of the digestive tract is made up of two divisions, — an anterior division, the small intestine, and a posterior division, the large intestine.

The **small intestine** is further divided into three parts, — the duodenum, the jejunum, and the ileum. The **duodenum** is that portion immediately posterior to the stomach. Note the sharp turn it makes as it leaves the pyloric end of that organ. It is five or six inches in length and U-shaped, and between its two limbs lies a portion of the light-red pancreas. Turn the intestine to the left and the course of the duodenum will be seen. No definite boundary separates the duodenum from the **jejunum**; this division and the **ileum** each forms about half the remaining part of the small intestine. Lift them up and note the mesentery which joins them with the dorsal body wall, but do not cut it. The hinder end of the ileum will be seen to lie on the right side of the body, where it joins the large intestine.

The **large intestine** is divided into the colon and the rectum. The **colon,** the anterior division, is a thick tube which lies back of the liver and stomach against the dorsal body wall. The ileum does not join the colon at the anterior end of the latter, but a short distance from it, and the blind sac thus formed is called the **cæcum.** This pouch is a rudiment of a division of the intestine, which in many vegetarian animals, as the rabbit, is very long; in man the hinder portion of it is the vermiform appendix. The colon may be divided into three parts, — the **ascending colon,** the short anterior portion which lies on the right side of the animal and extends forward; the **transverse colon,**

which extends transversely to the left; and the **descending colon**, which extends back to the **rectum**. This last-named portion of the large intestine extends along the middorsal line of the body cavity to the **anus**. Its anterior end is not sharply separated from the colon; its posterior end is constricted. Note the mesentery which joins the large intestine with the dorsal body wall, but do not cut it.

In order to study the hinder end of the rectum, the pelvis must be split in the midventral line, which is easily accomplished with a scalpel by cutting the midventral suture. Grasp one of the legs firmly in each hand and bend them sharply back, thus making a space an inch or more in width between the two halves of the pelvis and exposing the rectum.

Exercise 7. Draw a sketch of the abdominal cavity with the great omentum removed, showing the natural position of the organs exposed. Carefully label all.

Study the form and position of the **liver** and **pancreas**, but without cutting them or any of their connections. The **liver** is divided into two main lobes, — the **right** and the **left lobe**, between which is the ~~**suspensory**~~ **ligament**. Note carefully the minor lobes into which each of these lobes is divided. Turn the hinder end of the liver forward and pin it there, and observe its dorsal and posterior surfaces. Note carefully the lobes which appear in this view. The **gall bladder** will be seen in the right lobe.

Turn the entire intestine as far as possible to the animal's left without cutting the mesentery, and fasten it there. The dorsal wall of the abdominal cavity will thus be exposed. Note the large right **kidney** on the right side, just back of the liver, usually imbedded in fat. Two large veins will be seen, the larger of the two, and the largest vein in the body, being the **postcaval**. This vein lies in the median plane near the dorsal body wall, between the two kidneys, from each of which a prominent **renal vein** will be seen going to it. It passes forward into one of the divisions of the right lobe of the liver, on its way to the heart. The other vein is the **superior mesenteric vein** and its forward continuation, the **portal vein**. The superior mesenteric lies in the

mesentery, in the loop of the duodenum, alongside the pancreas; the portal lies in front of the loop and passes to the dorsal surface of the liver, where it breaks up into a number of branches which enter the various lobes.

Lying alongside these branches of the portal vein are the much smaller **bile ducts**, which collect bile from the lobes of the liver. A duct from the gall bladder, called the **cystic duct**, joins these bile ducts, and the union of all of these forms the **common bile duct**, which lies alongside the portal vein and carries the bile to the duodenum. Trace these ducts; if they are not easily seen, they may often be made apparent by squeezing bile into them from the gall bladder.

The **pancreas** is a long, flat gland four or five inches in length. It has two limbs which lie at right angles to each other. One of these lies in the loop of the duodenum; the other extends to the left side of the body cavity along the dorsal surface of the stomach. The pancreas communicates with the duodenum usually by two ducts. The **pancreatic duct** lies near the bend of the pancreas, joins the common bile duct, and enters the duodenum with it; the **accessory pancreatic duct**, which is sometimes wanting, enters the duodenum about an inch back of it.

A number of large, soft **lymph glands** are present in the mesentery, the largest of which is about two inches in length and situated near the center of the mesentery; it is called the **pancreas Aselli**, but is not a pancreas.

Exercise 8. Make a semidiagrammatic sketch showing the dorsal and posterior surfaces of the liver, the pancreas, and the duodenum, the bile and pancreatic ducts, and the branches of the portal vein on the surface of the liver, so far as observed.

The study of the digestive tract will be finished after that of the portal veins.

The vascular system. This is composed of the following organs: (1) the heart, (2) the arteries, (3) the veins, (4) the capillaries, and (5) the lymph vessels. The **heart** is a muscular pump containing two auricles and two ventricles; it drives the

blood through two systems of **arteries**, — (*a*) the **pulmonary arteries**, which take venous blood from the right ventricle to the lungs to be aërated, and (*b*) the **systemic arteries**, which take arterial blood from the left ventricle to the various tissues and organs of the body. The heart receives blood through two systems of **veins**, — (*a*) the **pulmonary veins**, which bring arterial blood from the lungs to the left auricle, and (*b*) the **systemic veins**, which bring venous blood from the tissues and organs of the body to the right auricle.

The systemic veins may be further subdivided into two systems, — (*a*) the **caval system**, by which the blood is brought directly to the heart, and (*b*) the **portal system**, by which the blood is taken from the digestive tract and spleen directly to the liver, from which organ it goes to the heart through the hepatic veins.

The portal system. This system consists of the portal vein and several smaller veins which meet to form it. The **portal vein** and the **superior or anterior mesenteric**, the largest of its tributaries, have just been observed. The latter joins the former near the pyloric end of the stomach, bringing blood from the intestine. Observe, without cutting the mesentery, the **mesenteric veins** which radiate to the superior mesenteric from every part of the small intestine. A single large branch of the latter vein called the **inferior** or **posterior mesenteric** brings blood from the large intestine. The **gastrosplenic vein** joins the portal near the base of the superior mesenteric; it is formed by the union of branches from the spleen, stomach, pancreas, and great omentum. Besides these veins the portal also receives a number of smaller veins from the duodenum, pancreas, and the stomach.

Study all of these veins, but without cutting the mesentery in which they lie. Note also that alongside the mesenteric veins lie the mesenteric arteries. These arteries are somewhat smaller than the veins which accompany them and are a light pink in color, while the veins are dark-colored.

Exercise 9. Draw a diagram showing the portal system.

The digestive system (*continued*). Lift up the intestine and cut the mesentery where it joins it; cut also the bile and the

pancreatic ducts. Straighten out the intestine from the stomach to the anus. Be careful, however, not to injure the bladder, which lies ventral to the rectum. The two ureters, also, which join the bladder with the kidneys and appear as white cords, and in the male the vasa deferentia, which also appear as white cords lying ventral to the rectum, must be carefully preserved. Find the anterior or cardiac end of the stomach and note the œsophagus which comes through the diaphragm from the thoracic cavity and joins it. With scissors cut the œsophagus; cut the connections of the stomach and take it and the intestine from the body.

Exercise 10. Draw an outline of the stomach and duodenum, the hinder part of the ileum, and the large intestine. Label all carefully.

Cut the rectum at the level of the bladder, taking care not to injure the ureters and, in the male, the vasa deferentia. Slit open the stomach and note the longitudinal folds of its mucous membrane; at its pyloric end note the **pyloric valve**, a constriction caused by the thickening of the circular muscles of the stomach at this point. Slit open the duodenum and note its velvety appearance, which is caused by the presence of the **villi**, delicate fingerlike projections of the mucous membrane. Slit open the hinder end of the ileum, together with the cæcum and the forward portion of the colon, and note the **ileocolic valve**, a projection of the inner wall of the ileum into the colon which permits substances to pass in one direction only.

Exercise 11. Make a drawing showing the ileocolic valve.

The urogenital system. This system includes the urinary and the genital organs. Although these two groups of organs are quite different in function they bear a close topographical relation to each other and will be studied together.

The **urinary system** consists of a pair of kidneys, a pair of ureters, a urinary bladder, and a urethra. The **kidneys** are large, reniform bodies, which lie against the dorsal body wall on either side of the spinal column in the middle of the abdominal cavity;

the right kidney lies somewhat in advance of the left one. The peritoneum stretches over the ventral surface of the kidney and holds it tightly against the muscles of the body wall, and around its sides between the peritoneum and the muscles is a great accumulation of fat. On the medial side of the kidney is the slight concavity called the **hilus**, where the ureter and renal vein leave it and the renal artery enters it. The artery enters the body of the kidney; the branches of the vein will be seen on its outer surface.

The **ureter** is a long tube which passes along the dorsal body wall on one side of the vertebral column from the kidney to the dorsal surface of the neck of the bladder. It has the appearance of a white cord and is often imbedded in fat. Its anterior end is called the **pelvis**; this is a funnel-shaped sac, the large end of which is imbedded in the kidney and catches the urine as it oozes from the mouths of the kidney tubules, while its small end emerges from the hilus as the ureter proper. In the male animal the two ureters, near their hinder ends, pass through the loops made by the two vasa deferentia.

Remove the fat from the kidney and the ureter on the right side of the animal; be careful not to cut the latter or any of the veins or arteries near it. The large median vein between the kidneys is the postcaval vein; the large median artery is the dorsal aorta. The renal vein and the renal artery on each side will also be seen.

The **urinary bladder** is a muscular, pear-shaped sac which lies in the hinder part of the abdominal cavity between the rectum and the ventral body wall. Its larger end is directed forward; its smaller end, the **neck**, receives the ureters, and is directed backward. In the male animal the neck is continued in the form of the **urethra** or **urogenital canal**, and receives the vasa deferentia, which bring spermatozoa from the testes. It passes through the penis, at the distal end of which is the external opening, and becomes the common outlet for both urinary and genital organs. In the female the neck of the bladder opens into the **urogenital sinus** or **vestibule**, a short, wide space which also receives the vagina and is equivalent to the urogenital canal of the male; it opens to the outside through the **vulva**.

The bladder is supported by three mesenteries, — the median, ventral **suspensory ligament**, and the two **lateral ligaments** which join it with the dorsal body wall.

Exercise 12. Draw a semidiagrammatic sketch of the urinary system.

Remove one of the kidneys from the body, split it longitudinally, and study the cut surface. The kidney will be seen to be made up of a light-colored peripheral layer, which is called the **cortical substance**, and a darker central mass called the **medullary substance.** The kidney tubules will be seen as fine lines which converge to a large space near the concave side called the **sinus.** It contains the wide, funnel-shaped anterior end of the ureter which, as we have already learned, is called the **pelvis.** The opening of the sinus to the outside, through which the ureter emerges, is the **hilus.**

Exercise 13. Make a drawing of the cut surface of the kidney.

The **suprarenal** or **adrenal bodies** are a pair of ovoid bodies which lie imbedded in fat immediately in front of the kidneys. Their function is unknown.

The **genital organs** in the **male** are the following: a pair of genital glands called the testes, which lie in an integumental pouch called the scrotal sac, situated just ventral to the anus; a pair of efferent canals, through which the spermatozoa are conducted away from the testes to the urogenital canal; two sets of glands, — the bilobed prostate gland and the paired Cowper's glands, — which furnish the fluid in which the spermatozoa are suspended; and the penis, through which the urogenital canal or urethra passes to the external opening at its distal end.

Each **efferent canal** is made up of two portions, — the **epididymis** and the **vas deferens.** The vasa deferentia have already been seen. Each appears as a long white cord which forms a loop around the ureter and enters the neck of the bladder. Follow one of them to the bladder. Follow it in the opposite direction; it may be traced back to the muscular wall of the abdominal

cavity, through which it passes by a small opening called the **inguinal canal**, and finally proceeds to the **testis**. Carefully remove the skin from the scrotal sac, and from the penis, which lies between the testes.

The **scrotal sac** will be seen to contain two compartments, in each of which lies a testis. Expose one of the testes. It is a compact elliptical body composed of a mass of tubules which may be seen through the outer covering; these are the **seminiferous tubules** and produce the spermatozoa. The testis is closely invested by a fold of the peritoneum, which here forms a very deep, narrow pocket extending into the scrotum from the abdominal cavity, with which the testis is joined by the **spermatic cord**. This cord is made up of the slender anterior portion of this peritoneal pocket, and the vas deferens, spermatic artery, and spermatic vein, which give the cord its solid appearance; they form the connection between the testis and the organs of the abdominal cavity. When we remember that the testes have migrated from their original position near the kidneys, through the muscles of the abdominal wall to the scrotum, carrying the vasa deferentia and the blood vessels with them, we can understand how the spermatic cord has come into existence.

On the medial surface of the testis and at its two ends is a white, bandlike mass of convoluted tubes. This is the **epididymis**, the beginning of the efferent duct of the testis. It is composed of three parts, — the **caput epididymis**, which caps the anterior end of the testis, a band extending from the caput along its inner side to the posterior end, and the **cauda epididymis**, the enlarged posterior end.

The caput epididymis is joined with the seminiferous tubules of the testes by minute vessels called the **vasa efferentia**. The **vas deferens** begins at the cauda epididymis, passes forward with many convolutions along the inner side of the testis, and finally, as a part of the spermatic cord, passes through the inguinal canal into the abdominal cavity and to the neck of the bladder. Surrounding the ends of the vasa deferentia is the bilobed **prostate gland**. About an inch back of this gland are the paired

Cowper's glands, directly back of which the urethra enters the **penis**. This structure is formed of three elongated cylindrical bodies, — the median ventral **corpus spongiosum**, through which the urethra runs, and the two lateral **corpora cavernosa**. The latter diverge to the right and left at their proximal ends and form the **crura penis**. The distal end of the penis is formed by the greatly enlarged end of the corpus spongiosum and is called the **glans penis**; a fold of skin called the **prepuce** projects over it. A small bone is present just above the urethra, near its distal end.

The **female genital organs** are the following: a pair of genital glands called the ovaries, which produce the ova; a pair of efferent ducts which receive the ova and in which the young go through their fetal development; and the urogenital sinus. Each efferent duct is composed of the Fallopian tube, the uterus, and the vagina.

The **ovaries** are small, bean-shaped bodies, less than half an inch long, which lie a short distance back of the kidneys, near the dorsal body wall. Each is held in place by a broad mesentery, the **ligamentum uteri**, which passes from the uterus to the dorsal body wall and holds the ovary in one of its folds. The narrow **ligamentum ovarii** joins it with the ventral body wall. Examine the ovary with a hand lens and note the fine white points which give its surface a granular appearance; these are the **Graafian follicles**, in each of which is an ovum. **Corpora lutea** — follicles which have discharged their ova — may also be present and will appear as red elevations.

The anterior end of the efferent duct is the **Fallopian tube** or **oviduct**. It is a narrow, convoluted tube, with a very wide, open anterior end, called the **ostium**, the fluted edges of which are partly thrown around the ovary and catch the ova as they emerge. The posterior end of the Fallopian tube is continuous with the uterus.

The **uterus** is a large, Y-shaped structure; it consists of a posterior median portion, or **body**, and an anterior paired portion composed of two **horns**, which extend from the body to the Fallopian tubes. The posterior end of the uterus projects into

the vagina, forming the **cervix uteri**, or neck of the uterus. The uterus is attached to the dorsal body wall mainly by the ligamentum uteri.

The **vagina** extends from the uterus to the urogenital sinus; it lies beneath the rectum and just above the neck of the bladder.

The **urogenital sinus** is a short, wide tube which opens to the outside through the **vulva**, immediately beneath the anus. The opening of the bladder into it is ventral to that of the vagina. Arising from the floor of the sinus, just beneath the former, is a slight elevation, the **clitoris**, which is homologous to the penis of the male.

Exercise 14. Draw a semidiagrammatic view of the genital organs.

The vascular system (*continued*); **the caval veins.** We shall now begin to study the veins which carry venous blood directly to the heart. Three groups of these veins are present: (1) the precaval vein and its branches, which bring blood from the forward part of the body; (2) the postcaval vein and its branches, which bring blood from the hinder part of the body; and (3) the coronary veins, which bring blood from the walls of the heart itself.

The postcaval system. The anterior, thoracic portion of the postcaval vein will be observed later when the organs of the thoracic cavity are studied. Its abdominal portion arises in the hinder part of the abdominal cavity, and passes forward near the median plane between the kidneys to the right lobe of the liver, through which it passes. It then pierces the diaphragm and enters the thoracic cavity.

Press the liver back and observe this large vein passing through the diaphragm from the liver. Press the liver forward and note where the vein enters it from behind. Find the two **renal veins**, which come to it from the kidneys. The postcaval will be seen to be formed in the hinder part of the abdomen by the union of two large veins, the **common iliacs**, which bring blood from the hind legs.

As the vein passes forward from this point it receives the following veins, all of which are paired, but the members of a pair not always meeting the postcaval in the same transverse plane: the **iliolumbalis veins**, which join the postcaval just in front of the common iliacs, coming from the lumbar muscles; the **spermatic veins** (in the male), or the **ovarian veins** (in the female), which join the postcaval just behind the kidneys (the left vein often going to the left renal vein instead of to the postcaval); the **renal veins**, which bring blood from the kidneys; the **adreno-lumbalis veins**, which meet the postcaval just in front of the renal veins, bringing blood from the abdominal wall and the suprarenal bodies; the **hepatic veins** (variable in number), which enter the postcaval just behind the diaphragm, bringing blood from the liver; the **phrenic veins**, which meet the postcaval as it is passing through the diaphragm, bringing blood from that organ.

Observe the course of these veins; follow the postcaval through the liver and find the hepatic veins.

Study the **common iliac vein** and its branches, but do not injure the arteries which accompany them. About an inch from its anterior end it is formed by the union of two veins, — the smaller being the **internal iliac** or **hypogastric**, and the larger the **external iliac**. Note the small **caudal**, or **sacralis media vein**, which joins one of the common iliacs near its base. The internal iliac vein receives branches from the bladder, the genital organs, the rectum, and the muscles of the back and thigh. The external iliac is the principal vein of the hind leg. A short distance from its union with the internal iliac it receives the **deep femoral vein** from the muscles of the thigh. A branch of this vein, the **epigastric vein**, anastomoses with the internal mammary vein, which is a tributary of the precaval vein in the forward part of the body. The external iliac becomes in the leg the **femoral vein**. Follow it and its branches. Trace the epigastric and note its relation to the internal mammary.

Exercise 15. Draw a diagram showing the postcaval vein and its branches, so far as observed.

The arteries. Two groups of arteries may be distinguished: (1) the pulmonary arteries, which carry venous blood to the lungs; and (2) the aorta and its branches, which carry arterial blood to the tissues.

The **aorta** is the great artery which lies in the middorsal line of the body cavity and sends branches to all the various organs of the body. It is divided into two parts, the thoracic aorta and the abdominal aorta.

The **abdominal aorta** lies just beneath the spinal column in the abdominal cavity, and extends from the diaphragm to the hinder end of the trunk. It has been seen while dissecting the postcaval vein. Observe carefully its relation to this vein; remove the vein. Study the following branches of the aorta.

The **cœliac artery** is a large median artery which leaves the aorta about two inches behind the diaphragm. It soon divides into three main branches: the **hepatic artery**, which carries arterial blood to the liver and also sends branches to the duodenum, the stomach, and the pancreas; the **gastrica sinistra artery**, which goes to the stomach; and the **splenic artery**, which goes to the spleen and the pancreas.

The **superior mesenteric** or **anterior mesenteric artery** is also a large median artery which leaves the aorta a short distance behind the cœliac and takes blood to both small and large intestines and to the pancreas. Numerous branches go from it to these organs, which lie in the mesentery alongside the branches of the superior mesenteric vein. Near the base of this artery are two ganglia and a network of nerves, parts of the solar plexus.

The **adrenolumbar arteries** are paired vessels which pass to the muscles of the back; they also usually give off the **phrenic arteries**, which pass forward to the diaphragm.

The **renal arteries** are a pair of vessels which supply the kidneys and suprarenal bodies with blood.

The **spermatic arteries** (in the male), or the **ovarian arteries** (in the female), leave the aorta behind the kidneys and go to the genital organs. In the male each forms part of the spermatic cord.

The **inferior mesenteric** or **posterior mesenteric artery** is a small median vessel which supplies the large intestine.

The **iliolumbar arteries** are paired vessels which leave the aorta a short distance back of the inferior mesenteric and go to the muscles of the back.

The **lumbar arteries** are small paired vessels which pass from the dorsal surface of the aorta to the muscles of the back. Seven pairs are usually present and they are found from the diaphragm to the external iliacs.

The **external iliac arteries** are large paired vessels which, with their branches, supply the hind legs. Each external iliac gives off, just before it leaves the abdominal cavity, the **deep femoral artery**, which goes to the muscles of the thigh. A short distance from its beginning this artery sends out three branches, one of which, the **epigastric artery**, passes forward and anastomoses with the internal mammary artery, — a branch of the subclavian artery in the forward part of the body. The continuation of the external iliac is called the **femoral artery**, which, with its branches, supplies the greater part of the leg. Follow these branches.

The **internal iliac** or **hypogastric arteries** are paired vessels which leave the aorta a short distance behind the external iliacs; each sends branches to the bladder, rectum, urogenital organs, and muscles.

The **caudal** or **sacralis media artery** is the small continuation of the aorta which supplies the tail.

Exercise 16. Draw a diagram showing the abdominal aorta and its branches, so far as observed.

The thoracic cavity. Cut away the ventral and lateral walls of the thorax and thoroughly expose its cavity, but do not remove the diaphragm. The **heart** will be seen in its **pericardium.** Immediately in front of the pericardium is the **thymus gland,** an elongated pinkish organ of uncertain function. It varies much in size in different animals; in young animals it may project over the pericardium, while in old animals it is much smaller and may be almost entirely wanting. On each side of the heart will be seen the pleural sac with the lung.

Examine the **diaphragm** carefully. Note its position in the body cavity. Its general form is cup-shaped, the opening of the

cup looking toward the abdominal cavity. It will be seen to consist of a thin plate of muscle surrounding a transparent central tendon, the **semilunar tendon.** The muscular portion is made up of two parts, — the dorsal part, and the ventral and lateral part. The former, which is called the **vertebral portion,** extends from the semilunar tendon back to the vertebral column, the general direction of the fibers being longitudinal. The latter, the **sternocostal portion,** forms the larger part of the diaphragm; its fibers radiate from the semilunar tendon to the lateral and ventral sides of the thorax. The postcaval vein passes through the semilunar tendon; the œsophagus and aorta through the vertebral portion.

Remove the diaphragm. Make a hole in the pericardium and blow into it with the blowpipe to determine its extent. Remove the pericardium and the thymus gland, but without cutting any of the blood vessels. Study the heart and the thoracic blood vessels.

The **heart** is a large, conical body and lies nearly in the middle of the thorax; it is composed of two **ventricles** and two **auricles.** The posterior and much larger portion is formed by the ventricles. The walls of the right ventricle are thin and flabby; those of the left ventricle are thick and firm and include the apex of the heart. The auricles lie at the forward end of the heart and appear as a pair of thin-walled sacs. The greater part of each auricle is dorsal in position, with an extension onto the ventral side called the **right** and the **left auricular appendix** respectively.

The two auricles may be distinguished from each other by their difference in color, the right auricle being much darker than the left because of the dark-colored venous blood it contains. The septum separating the two ventricles is indicated on the ventral surface by the position of the coronary artery, which emerges from beneath the left auricle and runs to the right of the apex on the outer surface of the heart.

Study the great blood vessels of the thorax and their relation to the heart. Thoroughly dissect the fat and other loose tissues from them, being very careful not to cut them. Note the numerous

nerves which accompany and surround many of the vessels at the forward end of the heart; these are branches of the sympathetic and vagus nerves.

Extending forward from the anterior end of the heart are three large vessels. The most conspicuous is the great **precaval vein**, which is dark red in color and lies at the right of the median plane. The other two will be seen emerging from between the right and left auricles; they are the **pulmonary artery** and the **aorta**. The former springs from the right ventricle, on the ventral side of the heart, and is seen passing diagonally forward to the animal's left; it divides almost immediately into the **right** and **left pulmonary arteries**, which carry venous blood to the right and left lungs. These arteries may be brought into view by turning the heart forward.

The **aorta**, which carries arterial blood to the entire body, issues from the left ventricle just dorsal to the pulmonary artery. It almost immediately makes a sharp turn to the animal's left, and passes to the middorsal line of the thoracic cavity, where it runs posteriorly just beneath the vertebral column to the hinder end of the body cavity; it is thus composed of two divisions, — the thoracic aorta and the abdominal aorta.

Study the **thoracic aorta** and its branches, but do not follow them out of the thoracic cavity.

The two small **coronary arteries** leave the aorta at its base and supply the walls of the heart with blood. If the left auricle be turned forward, the base of these arteries will be seen; later, when the heart is dissected, they may be traced to the aorta.

The **innominate artery** is the first large vessel which passes forward from the arch of the aorta, and lies parallel with the precaval vein; note the nerves which lie along its left side. It gives off the small **mediastinal artery** and then divides into three branches, — the **right** and the **left carotid arteries**, which carry blood to the head, and the **right subclavian artery**, which goes to the right fore leg.

Immediately to the left of the innominate artery is the **left subclavian artery**. It passes forward parallel with the innominate and goes to the left fore leg.

Joining the aortic arch with the pulmonary artery is the short **ligamentum Botalli.** It is the rudiment of an artery called the **ductus Botalli,** which in the embryo joins these vessels and turns the blood of the right ventricle into the aorta instead of permitting it to go to the lungs. In young cats this ligament is large; in old cats it is small or wanting.

Turn the left lung over to the right and observe the aorta as it passes posteriorly in the middorsal line of the thoracic cavity. Ten pairs of small **intercostal arteries** will be seen arising from its dorsal side and passing to the muscles of the back. Two small **bronchial arteries** also branch off either from the aorta near the fourth intercostals, or from these intercostals themselves, and extend along the bronchi to the lungs. A number of small arteries also go to the œsophagus.

Exercise 17. Draw the ventral aspect of the heart and the thoracic blood vessels just mentioned.

Turn the apex of the heart to the left side and pin it there. Study the dorsal surface of the heart. Find the right and the left auricles. Note the precaval vein entering the right auricle; a short distance from the base of this vein it is joined by the **azygos vein.** This is a median vein which arises in the abdominal cavity and extends along the middorsal line of the thorax to the precaval. It receives the paired **intercostal veins,** and is homologous to the right posterior cardinal vein of fishes.

Entering the posterior margin of the right auricle will be seen the large **postcaval vein,** which brings the blood of the entire hinder part of the body; it receives no branches in the thorax. Beneath the base of the postcaval the largest of the **coronary veins,** which bring blood from the wall of the heart, enters the right auricle.

Entering the left auricle are the **pulmonary veins,** which bring arterial blood from the lungs. They are arranged in three groups, each of which contains two or three veins. The right-hand and the left-hand groups bring blood from the anterior and middle lobes of the right and the left lungs respectively,

the posterior group from the posterior lobes of both lungs. Follow them to the lungs and note their distribution.

Exercise 18. Draw the dorsal aspect of the heart with the veins just mentioned.

The precaval system. The precaval vein and its posterior branch, the azygos vein, have already been observed. A short distance in front of the azygos the precaval receives the **internal mammary veins**; they unite and form a single vessel, which joins the precaval opposite the third rib. Each internal mammary may be followed posteriorly to the abdominal cavity, where it anastomoses with the epigastric vein.

The precaval vein is not long; it is formed by the union of the two large **innominate veins.** These are also short; they are diagonal in position and each is formed by the union of the external jugular vein, which comes from the head, and the subclavian, from the shoulder and fore leg. The innominate usually receives a single tributary, which is formed by the union of the vertebral and costocervical veins, although these are subject to considerable variation. The **vertebral veins** return blood from the cranial cavity; they lie, one on each side, in the vertebrarterial canals of the anterior six cervical vertebræ; the **costocervical veins** bring blood from the muscles of the back and neck.

The **subclavian** forms the proximal portion of the system of veins which brings blood from the shoulder and the fore leg; lateral to the wall of the thorax it is called the **axillary vein,** which receives several small tributaries and is formed by the union of two veins, the **subscapular** and the **brachial.** The former of these brings blood from the shoulder. The brachial vein comes from the leg. Follow these veins and their branches on the right side of the body, being careful not to injure the arteries which accompany them.

The **external jugular vein** lies just beneath the skin on the side of the neck. It receives, near its base, the **internal jugular vein.** Follow this large vein and the external jugular forward on the right side of the body. The internal jugular lies at the side of the trachea alongside a prominent nerve, the vagus, and the

carotid artery; it arises at the base of the skull and returns blood from the brain. The external jugular is formed at the base of the head by the union of the **anterior facial vein,** which arises beneath the eye and brings blood from the lower portion of the face, and the **posterior facial vein,** which collects blood from the upper and hinder portions of the head. Near their origin the right and left external jugulars are connected by the **transverse vein,** which passes across the throat.

Near the base of the internal jugular the external jugular receives the **thoracic duct.** This is the main lymph canal of the body; it comes from the region of the large mesenteric lymph glands and lies along the left side of the aorta and the œsophagus. It will be seen with difficulty, if at all.

Note the **thyroid gland.** It is a large double gland near the forward end of the neck; it consists of two elongated lobes, which lie on either side of the trachea, and a ventrally situated connecting lobe.

Exercise 19. Draw a diagram showing the veins of the precaval system, so far as observed.

The anterior arteries. Study the **right subclavian artery** and its main branches. The first of these to leave the subclavian is the **vertebral artery.** This artery branches off from the dorsal side of the subclavian at the first rib, passes forward, and enters the vertebrarterial canal, in which it goes to the head. It enters the foramen magnum and, joining the left vertebral artery, forms the median **basilar artery** of the brain.

The **internal mammary artery** leaves the ventral side of the subclavian near the vertebral artery and passes back along the inner surface of the sternum to the abdominal cavity, where it finally anastomoses with the epigastric artery.

The **costocervical artery** arises from the subclavian just back of the vertebral artery; it divides at once into two branches which supply the intercostal muscles and the muscles of the back and sides.

The **thyrocervical axis** arises opposite the internal mammary artery and passes forward to the muscles of the shoulder and neck and to the thyroid gland.

The continuation of the subclavian is called the **axillary artery.** It lies immediately behind the brachial plexus, which is a network of large nerves in the axillary region. It gives off two small arteries and then divides into the **subscapular** and the **brachial.** The former passes toward the shoulder, where it gives off branches which supply the muscles of the shoulder. The brachial artery goes to the arm, which it supplies with blood. Follow these arteries and their branches.

Exercise 20. Draw a diagram showing the distribution of the subclavian artery and its branches, so far as observed.

Study the **right carotid artery** and its branches, which passes forward alongside the trachea to the head. Just in front of the thyroid gland it gives off the **thyroid artery.** The **muscularis artery** branches off very near the thyroid and goes to the muscles of the neck. At the base of the neck the large **lingual artery** goes to the under side of the face and to the tongue, and the **external maxillary** to the side of the face. At the base of the ear the **posterior auricular artery** passes to the muscles of the ear and the head, and the **temporal artery** also to the muscles of the head. The carotid artery then ends in a network of small arteries near the base of the jaw, called the **carotid plexus.**

Exercise 21. Draw a diagram showing the distribution of the carotid artery and its branches so far as observed.

The internal structure of the heart. Remove the heart from the body, cutting its veins and arteries a short distance from it, and dissect it under water. Pin the heart with the ventral side uppermost and thoroughly dissect away the loose tissues from the stumps of the aorta and the pulmonary artery. Identify the ligamentum Botalli, which joins the two, and cut it. Note at the base of the aorta the beginning of the coronary arteries. Pin the heart with the dorsal side uppermost; identify and clean the stumps of the precaval, postcaval, and pulmonary veins.

Slit open the dorsal wall of the right auricle and its appendage, but without injuring the caval veins, and wash out the

blood inside. Note the network of muscles on the inner surface, also the openings of the caval veins into the auricle. Just posterior to the postcaval opening is that of the small coronary vein, in front of which is a valve. Observe the **auricular septum**, which separates the two auricles, and the oval depression, the **fossa ovalis.** In the embryo an opening called the foramen ovale is present at this place, through which the fetal blood passes directly from the right to the left auricle, instead of going first through the right ventricle and to the lungs. Note the large **auriculo-ventricular aperture** into the right ventricle.

Open the right ventricle by slitting the pulmonary artery longitudinally and continuing the incision to the hinder end of the ventricle. Note the thinness of the walls of the ventricle and the muscular ridges on the inner surface. Guarding the auriculo-ventricular aperture is the large **tricuspid valve,** which consists of a long membranous flap attached at its free end to the wall of the ventricle by long tendinous and muscular cords, the **chordæ tendineæ.** The opening of the ventricle into the pulmonary artery is guarded by the three pouched **semilunar valves,** which permit the flow of blood only in one direction. Look for them with the aid of the blowpipe.

Slit open the dorsal wall of the left auricle, but without cutting the pulmonary veins. Note the three openings of the pulmonary veins, and the large **auriculo-ventricular aperture.**

Open the left ventricle by slitting the aorta and continuing the incision through the ventricle to the apex of the heart, and study the interior. Note the thickness of its walls. The auriculo-ventricular aperture is guarded by the **bicuspid** or **mitral valve,** which consists of two distinct flaps joined with the ventricular wall by chordæ tendineæ. The opening into the aorta is guarded by three **semilunar valves,** one of which is dorsal and the other two lateral. Note the two prominent muscular ridges — the **columnæ carneæ** — in the wall of the ventricle.

Exercise 22. Draw a diagrammatic view showing the four cavities of the heart and their apertures and valves.

Cut off the apex of the heart by a transverse incision a quarter of an inch from the end, showing the two ventricles and the relative thickness of their walls.

Exercise 23. Draw the cross section.

Exercise 24. Draw a diagram showing the entire vascular system.

The mouth and the pharynx; the salivary glands. Skin the head. Five pairs of these glands are present, all of which open into the mouth.

The **parotid glands** are the largest. Each is situated just beneath the skin and immediately below the ear; its duct passes through to the inner surface of the cheek, where it opens into the mouth opposite the last premolar tooth.

The **submaxillary glands** are situated just below and behind the parotids. The duct of each runs forward and opens at the end of a papilla in the forward part of the floor of the mouth, near the median line.

The **sublingual glands** are situated in front of the submaxillaries and in contact with them. The duct of each passes forward and opens into the mouth at the apex of the same papilla.

The **molar gland** extends from just beneath the angle of the mouth posteriorly; it is very small and opens into the mouth by a number of ducts.

The **infraorbital gland** lies on the ventral wall of the orbit. It will be seen when the orbit is dissected. Its duct opens into the mouth just back of the upper molar.

Exercise 25. Draw an outline of the head and show the position of the salivary glands.

Cut away the lips and expose the **teeth.** Shut the jaws and observe the relation of the teeth of the lower jaw to those of the upper. The dental formula of the cat is the following: incisors $\frac{3}{3}$, canines $\frac{1}{1}$, premolars $\frac{3}{2}$, molars $\frac{1}{1}$. The milk teeth of the young cat lack the molars.

Exercise 26. Draw a front and also a side view of the closed mouth, with outlines of the teeth.

Cut through the muscles on each side of the head from the angle of the mouth to the end of the jaw. Disarticulate the lower jaw, first cutting it with bone forceps, if necessary, and turn it down, exposing the cavities of the **mouth** and **pharynx.** The two cavities form a single space which extends from the lips to the beginning of the œsophagus. The mouth is much the larger of the two spaces, and extends from the lips to the free edge of the soft palate; the pharynx lies between this point and the œsophagus, and is the space in which the path of the respiratory air from the nostrils to the lungs crosses that of the food from the mouth to the stomach.

The **mouth cavity** itself is made up of two regions, — the **vestibule,** which is that part between the lips and cheeks and the jaws and teeth; and the **mouth proper,** or that part between the teeth and the soft palate. A median fold called the **frenulum** unites the upper lip with the jaw. The lower lip and the lower jaw are also united by frenula, not only in the median plane but also on each side just back of the canine teeth.

The roof of the mouth is formed by the hard and the soft palate. The **hard palate,** which forms the anterior portion, is characterized by a number of curved, transverse ridges, between which are rows of papillæ. Between the anterior ridge and the incisor teeth is a large median papilla, on each side of which is the opening of the duct leading to the **organ of Jacobson,** a small sensory organ of uncertain function which lies on the floor of the nasal cavity.

The **soft palate** is the soft flap which forms the hinder portion of the roof of the mouth; it will be seen to be much narrower than the hard palate. The narrow space forming the hinder part of the mouth cavity, which is bounded dorsally by the soft palate and by the root of the tongue ventrally, is called the **isthmus faucium.** Diverging from either side of the soft palate to the side of the tongue and the ventral wall of the pharynx are two folds called the anterior and the posterior **pillars of the fauces.** From each of the lateral sides of the isthmus between these pillars a prominent lobed gland called the **tonsil** projects into the cavity.

The floor of the mouth is formed principally by the **tongue**, which is a muscular organ projecting from it. The free end of the tongue is joined with the floor of the mouth by means of a median fold called the **frenulum linguæ**.

The upper surface of the tongue is provided with three kinds of papillæ, — the filiform, fungiform, and circumvallate. The **filiform papillæ** cover the upper surface, those on the middle and forward portions having sharp, horny tips which form the rasping surface peculiar to carnivorous mammals; the **fungiform papillæ** are enlarged at their free ends, and are the prominent projections in the middle and at the sides of the tongue near its root, those at the sides being very large; the **circumvallate papillæ** are prominent projections, each surrounded by a circular groove and a ridge, which are present in two rows of two or three papillæ each, at the posterior part of the tongue between the lateral fungiform papillæ.

The **pharynx** lies just back of the soft palate. Two passages open into it at its anterior and two at its posterior end. The two anterior passages are the **isthmus faucium**, the hinder end of the mouth, and the **nasopharynx**. This latter space is a part of the respiratory passage. It lies immediately above the soft palate and the hinder part of the hard palate, and communicates posteriorly with the pharynx and anteriorly with the nasal cavities. Probe it and determine its extent.

The two posterior openings of the pharynx are the **œsophagus** and the **glottis**. The latter is the opening into the larynx and is ventral to the œsophagus; it is guarded by the **epiglottis**, a triangular cartilage which acts as a valve and closes the glottis when food is passing through the pharynx.

Exercise 27. Draw a diagrammatic sketch showing the cavity of the mouth and pharynx.

The respiratory system. This system consists of the nasal cavities, the nasopharynx, the pharynx, the trachea with the larynx, the bronchi, and the lungs.

The **nasal cavities** are two in number and lie side by side in the anterior portion of the head, separated by a median partition,

the **nasal septum.** They communicate with the outside by the **nostrils** or **anterior nares,** and with the nasopharynx by the **posterior nares.** Cut away the soft palate and the hinder part of the hard palate and expose the nasopharynx and the posterior nares. Note a pair of slits in the lateral walls near the middle of the nasopharynx; these are the openings of the **Eustachian tubes,** which join the middle ear with the pharynx.

The nasal cavities are rendered very irregular in outline and are almost entirely filled by projections from their walls. These projections are called the **turbinals** and serve to increase the sensory surface; they will be studied with the skeletal system.

Make a transverse section of the anterior end of the nose, using a large scalpel. The cartilaginous nasal septum will be seen between the two nostrils. From its dorsal edge on each side a thin plate passes laterally, then ventrally, and finally dorsally, forming the sides of the cavity.

Exercise 28. Draw the transverse section.

Observe the **trachea** and the **larynx,** and the organs lying near them. Just dorsal to the trachea is the œsophagus, a long muscular tube which extends from the pharynx to the stomach. On each side of the trachea is the carotid artery and the internal jugular vein, and also a nerve cord which is composed of the vagus and sympathetic nerves closely bound together; these nerves must not be cut. Near the anterior end of the trachea is the thyroid gland.

Dissect from the body the tongue with its long supporting hyoid bones, the larynx and trachea, and the lungs, and bring them into a pan of water. Do not cut the nerve cord just mentioned. Note the relation of the hyoid apparatus to the larynx. Carefully dissect away the tongue and expose the hyoid. It will be seen to consist of a transverse median bone, the **basihyal,** and two pairs of **horns** or **cornua.** The anterior cornua are the longer and consist of four bony segments on a side; the posterior cornua are composed of a single bone on each side.

Study the **larynx,** first removing the muscles from its sides. The **glottis,** the opening into the larynx from the pharynx, is a

triangular slit in the floor of the pharynx, in front of which is the **epiglottis.** The larynx, which controls the passage of air into and from the lungs and produces the voice, is made up of plates of cartilage connected by ligaments and muscles. There are three large, unpaired cartilages, the **thyroid, cricoid,** and **epiglottis**; and a pair of small cartilages, the **arytenoids.** The thyroid cartilage is the large plate on the ventral and lateral sides, which forms the anterior ring of the larynx. The cricoid is just behind the thyroid; it forms a complete ring, which is wide dorsally and narrow ventrally. The arytenoid cartilages are two small triangular bodies which articulate with the anterior edge of the dorsal side of the cricoid cartilage, in the median line.

On either side of the glottis, at the base of the epiglottis, is a pair of fleshy ridges, the **false vocal cords**; the vibration of these cords is said to produce purring. Just behind these are the true **vocal cords.** They are a pair of ridges on the inner surface of the larynx, which converge from the arytenoid cartilages dorsally to the inner surface of the thyroid cartilage ventrally.

Exercise 29. Draw a semidiagrammatic sketch of the anterior end of the larynx, showing the false and the true vocal cords, together with the hyoid bones.

Study the **trachea,** the **bronchi,** — which are formed by the branching of the hinder end of the trachea, — and the **lungs.** The cartilaginous rings of the trachea are incomplete on the dorsal side where it lies against the œsophagus. The structure of the bronchi is similar to that of the trachea. The lungs are large-lobed organs, the right lung being divided into four lobes and the left lung into two: the anterior lobe of the left lung is subdivided into two lobes. A branch of the bronchus penetrates into each lobe. Dissect a branch of the bronchus and follow it as far as possible into the lung.

Exercise 30. Make a drawing of the ventral surface of the lungs, the bronchi, and the trachea.

The nervous system. This system is composed of (1) the **central nervous system,** or the brain and the spinal cord; (2) the

peripheral nervous system, which is composed (*a*) of the paired cranial and spinal nerves and (*b*) the sympathetic nervous system; and (3) the **special sense organs.**

We shall first study the spinal nerves and the sympathetic system.

Thirty-eight pairs of **spinal nerves** are present, of which eight are cervical, thirteen thoracic, seven lumbar, three sacral, and usually seven or eight caudal. With the exception of the first two pairs, all the spinal nerves pass from the neural canal through openings between the vertebræ, called **intervertebral foramina.** The first pair passes through a pair of foramina in the dorsal arch of the atlas, and the second pair between the arches of the atlas and axis. Each nerve arises from the spinal cord by two roots which join immediately outside the intervertebral foramen. Of these roots the dorsal one bears a ganglion and is sensory in function, while the ventral root is motor. Immediately after its formation by the meeting of these roots, the spinal nerve divides into two branches, — a smaller dorsal and a larger ventral ramus.

At each end of the trunk the spinal nerves unite and form a complicated network called a nerve plexus. That at the anterior end is the **brachial plexus.** It lies in the axillary region near the shoulder, and is formed of the ventral rami of the fifth, sixth, seventh, and eighth **cervical**, and the first **thoracic nerves**; the nerves which arise from it go to the arm and shoulder.

Identify the roots of these five nerves; that of the fifth cervical is the smallest, the others are large and conspicuous. Carefully free the plexus of the surrounding tissue and follow the main nerves which spring from it. The arrangement of the network is quite variable. The following are the principal nerves which leave the plexus.

The **radial nerve** is the largest. It arises from the seventh and eighth cervical and the first thoracic nerves, and is distributed to the muscles and skin of the fore leg.

The **median nerve**, which is formed by the union of branches from the seventh and eighth cervical and the first thoracic nerves, and the **ulnar nerve**, which springs from the eighth

cervical and the first thoracic, are large nerves which accompany the brachial artery into the leg.

The **musculo-cutaneous nerve** is formed by the union of branches of the sixth and seventh thoracic nerves. It supplies the biceps and other muscles of the upper arm and the skin of the forearm.

The **axillary nerve** is formed by branches of the sixth and seventh cervical nerves and passes to the muscles and skin of the shoulder.

The **subscapular nerves** are three in number; they arise from the sixth, seventh, and eighth cervical nerves and go to the subscapular muscle on the inner surface of the scapula.

The **suprascapular nerve** arises from the sixth cervical nerve and goes to the muscles of the outer surface of the scapula and to the integument of the upper arm.

The **phrenic nerve** is formed by the union of a branch from the fifth and one from the sixth cervical nerve; it passes directly back, at first along the subclavian artery, to the diaphragm.

Exercise 31. Draw a diagram of the brachial plexus and the nerves which issue from it, so far as observed.

The **thoracic spinal nerves**, with the exception of the first, do not enter a plexus, but go directly to the muscles of the back and side. Their dorsal rami are small; their ventral rami are large and are called the **intercostal nerves**; each lies alongside the hinder border of a rib, together with the intercostal artery. Find one of these nerves and trace it to the backbone, where the dorsal ramus will also be seen.

The first three **lumbar spinal nerves** do not enter a plexus. Their ventral rami divide a short distance from their medial ends into an anterior and a posterior division. Look for the first pair of lumbar nerves a short distance behind the last rib and beneath the muscle which forms the inner layer of the abdominal wall. The two divisions of the ventral ramus will here be found. Trace them medially and find the dorsal ramus. Find the second and third lumbar nerves.

The fourth, fifth, sixth, and seventh **lumbar nerves** and the three pairs of **sacral nerves** form the **lumbosacral plexus**; the nerves

issuing from it supply the hind legs and the hinder part of the trunk. This plexus is partly hidden by muscles and may be best studied by finding the nerves which issue from it and following them back to the plexus.

The largest of these nerves are the **great sciatic**, the **obturator**, and the **femoral nerves**. The first of these is the largest nerve in the body; it is a great cord which will be seen passing straight back through the pelvis. It is formed principally by the union of the sixth and seventh lumbar and the first and second sacral nerves. Trace it forward, thoroughly removing the muscle and fat which obscure it. Note its two largest roots, which are the seventh lumbar and the first sacral nerves. Follow the great sciatic into the leg.

Just in front of the great sciatic is the **obturator nerve**. Trace it forward; it will be found to be formed by the union of the sixth and seventh spinal nerves.

The **femoral** is a large nerve which is formed by the union of branches of the fifth and sixth lumbar nerves; it is covered up by a muscle, which must be removed. As it emerges from the abdominal cavity it divides into three nerves which supply the muscles of the thigh. One of these — the **saphenous** —is the long nerve which accompanies the femoral vein and artery.

The **genitofemoral nerve** arises principally from the fourth lumbar nerve and passes to the anterior surface of the thigh. It divides into two main branches; one of these passes through the longitudinal muscle which lies alongside the spinal column in the abdominal cavity, and appears on its ventral surface; the other passes posteriorly along the medial surface of this muscle.

The **lateral cutaneous nerve** arises principally from the fifth lumbar nerve and passes through the abdominal wall to the posterior side of the thigh.

Study the three **sacral nerves**. The first sacral is the hindermost of the two large nerves which form the main roots of the great sciatic nerve.

Exercise 32. Draw a diagram of the lumbosacral plexus and the nerves which issue from it, so far as observed.

The dorsal rami of the **caudal spinal nerves** supply the dorsal side of the tail; the ventral rami are connected with one another and with the last sacral nerve by a longitudinal nerve.

The **sympathetic system** consists of two rows of small ganglia which lie on either side of the spinal column against the dorsal wall of the body cavity and in the neck, those of each row being connected with one another by a longitudinal nerve, and with the spinal nerves by short branch nerves; they are also connected with various organs of the thoracic and abdominal cavities by numerous nerves which in certain places form plexuses.

The sympathetic system falls into three divisions, the **cervical, thoracic,** and **abdominal.** The thoracic and abdominal divisions which lie in the cavities of the same names are easily studied. The two longitudinal nerves will here be seen lying against the dorsal body wall on either side of the spinal column. In the abdominal cavity they lie nearer together than in the thoracic, gradually becoming smaller toward the posterior end of the abdominal cavity, where they finally come to an end. In both these cavities a pair of sympathetic ganglia is present opposite each vertebra, and a short connecting nerve joins each ganglion with a spinal nerve.

Look for the longitudinal sympathetic nerves, first in the abdominal cavity, where they lie against the vertebræ. Note the sympathetic ganglia here and follow the connecting nerves which join them with the corresponding spinal nerves. Follow then the longitudinal nerves into the thoracic region.

In the cervical region the longitudinal sympathetic nerve is so closely joined with the vagus that they appear like a single strand; this lies along the trachea together with the carotid artery and the internal jugular vein. A short distance in front of the first rib they separate from each other, and the sympathetic, which is the smaller and more dorsal of the two, passes into the thorax.

Three large ganglia lie in the course of the cervical portion of the sympathetic cord on each side, — the **anterior, middle,** and **posterior cervical ganglia**. The first of these marks the anterior end of the sympathetic system; it is a large ganglion just back of the

base of the skull on the side of the neck and close to the ganglion nodulosum of the vagus. The other two are at the base of the neck near the first rib, and are joined together by two nerves.

Two large nerve plexuses, the cardiac and the solar, and several smaller ones, belong to the sympathetic system. The **cardiac plexus** lies at the anterior end of the heart, around the base of the aorta and the pulmonary artery. The **solar plexus** lies between the fundus of the stomach, the dorsal portion of the diaphragm, the suprarenal bodies, and the aorta. It consists of two ganglia — the large **cœliac** or **semilunar ganglion** which lies near the superior mesenteric artery, and the smaller **mesenteric ganglion** — and of nerves which radiate from these ganglia in all directions. These ganglia are joined with the longitudinal sympathetic nerve by several nerves, of which the **great splanchnic** is the largest. This nerve separates from the sympathetic in the thorax, pierces the diaphragm, and goes directly to the cœliac ganglion.

Exercise 33. Draw a diagram of the sympathetic system, so far as observed.

The special sense organs; the nose. This has already been dissected. The entire surface of the nasal cavity is not provided with an olfactory mucous membrane. Of the two principal passages on each side, the lower one is purely respiratory in function and transmits air into the pharynx; the upper passage is olfactory in function and in it the olfactory nerve is distributed.

The eye. The eyeball, together with its muscles, glands, and other accessory organs, lies within a membranous sac called the **periorbita,** which almost completely fills the bony orbit. Toward the outside the eye is protected by the upper and lower eyelids and the nictitating membrane. The eyelids are folds of the skin; they have no eyelashes, but are covered with hair, like the rest of the body. On the inner surface of the lid, near the edge, are the **Meibomian glands**; they are oil glands and appear as parallel yellow bands.

The nictitating membrane is situated at the inner corner of the eye, over which it moves. Pull it with forceps. It is

stiffened by a cartilage whose position is shown by the ridge it produces. A thin transparent membrane called the **conjunctiva** covers the inner surface of the eyelids, the exposed surface of the eye, and both sides of the nictitating membrane.

Observe the exposed portion of the eyeball. The convex, transparent **cornea** forms its outer portion. The yellow **iris** will be seen, in the middle of which is the **pupil**, the opening through which light is admitted into the interior of the eye; the iris contains delicate muscle fibers by the contraction of which the pupil is made smaller.

Exercise 34. Draw a sketch showing the exposed portion of the eye and the lids.

Carefully cut away the eyelids and the bony arch which forms the lateral wall of the orbit. Observe the **lachrymal gland**; it is a large, flattened, reddish body, which often has the appearance of a broad muscle and lies close to the hinder side of the eyeball at the outer angle of the eye, in contact with the bony arch. The fluid furnished by the gland bathes the cornea and is then drained off through the two **lachrymal canals**, each of which opens at the edge of one of the lids near the inner angle of the eye. These two canals join to form the **nasolachrymal duct**, which passes through the bony wall of the orbit and opens into the nose.

The muscles of the orbit. Ten small muscles control the movements of the eyeball. Eight of these are straight muscles and pass from the inner portion of the orbit near the entrance of the optic nerve to the sides of the eyeball. Of these the four larger are called the **rectus muscles**; the four smaller, which lie between the rectus muscles, are the four heads of a single muscle, the **retractor**. The other two muscles are the **inferior** and **superior oblique muscles**. Besides these an eleventh muscle is present which moves the upper lid.

The lateral and posterior portion of the bony orbit being removed and the lachrymal gland identified, note the muscle which is the most anterior in position of those exposed. It lies on the outer side of the eyeball, parallel to the margin

of the cornea, and is the **inferior oblique.** It is inserted in the outer surface of the eyeball near the cornea and passes ventrally beneath the eyeball to its origin in the anterior surface of the orbit.

Inserted in the eyeball just back of the inferior oblique is a broad muscle which passes straight back to the hinder part of the orbit; this is the **external rectus muscle.** Along its posterior border lies the lachrymal gland; remove the gland, also any fat that may be present, and sharply define the sides of the muscle. On each side of it is one of the four heads of the **retractor muscle.**

Just beneath the middle of the inferior oblique is the insertion of the **inferior rectus muscle,** which passes straight back along the ventral side to the hinder part of the orbit.

Dorsal to the external rectus and separated from it by the head of the retractor muscle just mentioned is the **superior rectus muscle,** which arises in the hinder portion of the orbit and passes straight forward to its insertion in the dorsal surface of the eyeball. Passing over the outer surface of this muscle and parallel with it is a narrow strand of muscle which goes to the margin of the upper eyelid; it is called the **levator muscle** of the upper eyelid.

Just forward of the insertion of the superior rectus is that of the **superior oblique muscle.** Its tendon runs at right angles to that of the superior rectus toward the dorsal margin of the inner side of the orbit, where it passes through a fibrous loop; here its direction is changed and it goes antero-ventrally to the body of the muscle which lies against the medial side of the eyeball. Its origin is on the inner wall of the orbit, just in front of the optic foramen.

Cut the tendon of the superior oblique, press the eye ventrally, and find, on the medial side of the eyeball, the **internal rectus muscle,** which extends from its insertion near the dorsal margin of the eyeball straight back to its origin in the inner wall of the orbit. On each side of it is one of the heads of the retractor muscle.

Exercise 35. Draw a diagram showing the eyeball and its muscles.

Pull the eyeball forward and cut the optic nerve and the muscles. Remove the eyeball from the orbit and cut away the muscles and fat still attached to it. It will be seen to be a spherical structure the anterior surface of which is somewhat flattened. Its outer covering is the **sclerotic coat**, a thick, tough membrane of connective tissue, the anterior portion of which is the transparent **cornea**. The boundary between the cornea and the sclerotic is marked by a prominent white ridge.

With sharp scissors cut two large openings in the side of the eyeball, opposite each other, and study the interior of the eye. Carefully remove the other eye from the orbit and cut it in two by an equatorial incision. Note behind the pupil the large, transparent **crystalline lens**; do not disturb it. The layer just within the sclerotic is the **choroid coat**, the anterior portion of which is the **iris**. The choroid coat contains the blood vessels of the eye and the pigment. Within the white ridge of the sclerotic just mentioned the choroid is thickened by the presence of a large number of radiating ridges which form the **ciliary body**. This structure forms thus a broad black ridge around the inner surface of the eye. Extending inward from this ridge is a delicate membrane called the **suspensory ligament**; this is continuous with the transparent capsule in which the lens is suspended. Delicate muscle fibers are present in the choroid near the ciliary body, by which the position of the crystalline lens is changed when the focus of the eye is adjusted. A layer of cells, called the **tapetum lucidum**, which has a metallic sheen and reflects the light, is present in the choroid coat, in the region of the optic nerve; it causes the cat's eyes to shine in the dark.

The inner coat of the eye is the **retina**. It is a soft, delicate membrane which will often be found separated from the choroid; it is the sensitive portion of the eye, and is in direct connection with the optic nerve. The point where the nerve pierces the sclerotic and choroid coats and joins the retina is shown by a small round spot, called the **blind spot** because the sensitive elements of the retina are here absent. Anteriorly the retina gradually becomes thinner and ends on the inner

surface of the iris. Just behind the ciliary body it forms a serrated ridge called the **ora serrata.**

The **crystalline lens** is a large, double-convex, transparent body situated immediately behind the iris; its convexity is greater on the anterior than on the posterior side. It is suspended in a delicate capsule which is attached to the ciliary body by the **suspensory ligament.**

The interior of the eye is divided into two principal chambers by the lens and the iris. The posterior cavity is filled with a jellylike mass called the **vitreous humor**, the anterior cavity with a fluid mass called the **aqueous humor.**

Exercise 36. Draw a diagram showing the structure of the eye. Carefully label all of the parts.

The ear. The organ of hearing is made up of three parts,— the internal ear or membranous labyrinth, the essential auditory organ, which is situated in a bony capsule at the side of the cranium; the middle ear, or tympanic cavity, in which are the ear ossicles and the tympanic membrane; and the outer ear.

The **outer ear** is composed of the **external ear**, which extends above the head and receives the vibrations of sound, and the **external auditory meatus**, the canal which leads to the tympanic cavity. The external ear, whose movements are controlled by small muscles, is a thin plate of cartilage, covered on both sides by integument.

The middle ear. Cut away the cartilaginous walls of the external auditory meatus until the bony walls of the skull are reached. At the inner end of the meatus is the **tympanic membrane**, or eardrum, surrounded by a ridge of bone. Note its shape and the character of the membrane. The middle ear lies in the tympanic bulla, which is the spherical projection of the skull just back of the external ear. Entirely free this from the muscles which may be attached to it. With a strong scalpel cut away the medial wall of the bulla and expose its interior. This is divided into a medial and a lateral chamber by a bony partition extending from its lateral wall. Of these two chambers the lateral one is the tympanic cavity proper and contains

the ear ossicles; from the forward end the **Eustachian tube** goes to the nasopharynx. Note the round hole in the dorsal wall; this is the **fenestra rotunda.**

Carefully cut away the partition between the chambers until the inner surface of the tympanic membrane appears, and study it and the ear bones. There are three of these bones, — the **hammer** or **malleus,** the **anvil** or **incus,** and the **stirrup** or **stapes.** The hammer consists of two parts, — a slender handle and a large, irregularly shaped head. The handle extends across the dorsal portion of the tympanic membrane, above the hinder rim of which the head is situated. The anvil is a minute bone with two projections, which articulates with the head of the hammer by one of its limbs and with the stirrup by the other. The last named bone, which has the form of a stirrup, fits into the **fenestra ovalis,** an opening into the inner ear; this opening is just medial to the ridge surrounding the fenestra rotunda.

Exercise 37. Draw a diagrammatic sketch of the inner surface of the tympanic membrane, together with the hammer and the fenestra rotunda.

Thoroughly clean out the middle ear. Two minute muscles are present in it which are inserted in the hammer and the stirrup. Observe the grooves in the walls of the cavity.

Exercise 38. Draw a view of the walls exposed and show the two fenestræ and the Eustachian canal.

The inner ear. The **membranous labyrinth** is an irregular sac entirely inclosed in the bony capsule called the bony labyrinth. It communicates with the middle ear by two openings, — the fenestra ovalis and the fenestra rotunda, just mentioned, — and consists of three main portions, — the **vestibule,** the **cochlea,** and the **semicircular canals.** The cochlea is situated in the prominent ridge which appears just back of the fenestra ovalis. The vestibule is behind the cochlea, which extends from it on one side, while from the opposite side project the semicircular canals.

The bone within which the membranous labyrinth lies is very hard and thick, and a dissection of the labyrinth is impossible

without a special treatment of the bone. If, however, this portion of the skull be decalcified in a ten per cent solution of nitric acid, the labyrinth can be studied.

The central nervous system; the brain. Before removing the brain from the cranial cavity cut away the skin and the muscles from the head and the adjacent portions of the neck; remove also the tongue and the lower jaw. With bone forceps chip away the roof of the skull. Do not tear, if possible, the **dura mater**, the outermost of the coatings of the brain, which lies next to the inner surface of the skull, but press it away from the skull as the removal of the bone continues. Expose thus the dorsal and lateral surfaces of the brain. Take pains to preserve intact the olfactory lobes which form the anterior end of the brain. Special care must also be taken in removing the tentorium, the vertical bony partition which extends from the roof of the skull between the cerebrum and the cerebellum. Remove now the dura mater from the dorsal and lateral sides of the brain.

The brain and spinal cord are enveloped in three membranes, — the **dura mater**, the thick outer membrane, the **pia mater**, the thin inner membrane, and the delicate **arachnoid**, between the other two.

Study the dorsal surface of the brain. It is made up of five divisions, — the cerebrum, the anterior and largest division; the thalamencephalon; the midbrain; the cerebellum; and the medulla oblongata, which is continuous with the spinal cord. Of these five divisions the first and fourth occupy almost the entire dorsal surface. The **cerebrum** is divided by a median longitudinal cleft, called the **sagittal fissure**, into the two **hemispheres**, at the anterior ends of which are the **olfactory lobes**.

The area of the surface of the cerebrum will be seen to be very much increased by the presence of folds, the **gyri**, which are separated from one another by deep fissures called **sulci**. These gyri are characteristic of mammals, all of which, except the lowest, possess them. The surface of each hemisphere is divided into four principal gyri whose general position is longitudinal, and whose margins are not in all places distinct.

Lateral to the sagittal fissure is the **marginal gyrus**, which is sometimes double posteriorly. Lateral to this gyrus and separated from it by the **lateral sulcus** is the **suprasylvian gyrus**. Lateral to this gyrus and separated from it by the **suprasylvian sulcus** is the **ectosylvian gyrus**, the form of which is that of an inverted U. Between the limbs of this gyrus is the **Sylvian gyrus**, which forms an inverted V, the two limbs of which are separated by the short **Sylvian fissure**. Between the Sylvian and the ectosylvian gyri is the **ectosylvian sulcus**, which is not complete but is interrupted dorsally. On the ventrolateral surface, beneath the Sylvian fissure, is the **pyriform lobe**, which is continuous with the olfactory lobe. Just back of and above the olfactory lobe at the anterior end of the hemisphere is the **orbital gyrus**, and behind that the **sigmoid gyrus**, with the **presylvian** and **cruciate sulci** between them, the former being ventral to the latter. Along the hinder margin of the hemisphere is the **posterior gyrus**.

Behind the cerebrum is the **cerebellum**. Its surface is also marked by the presence of gyri and sulci, which have, however, a different appearance from those of the cerebrum. Three general regions are distinguishable, — the median **vermis** and the lateral **hemispheres**.

Back of the cerebrum and partly covered by it is the fifth division of the brain, the **medulla oblongata**. Posteriorly it decreases in width and is continuous with the spinal cord.

Exercise 39. Make a semidiagrammatic drawing of the dorsal aspect of the brain.

Chip away the side of the skull and expose the entire lateral aspect of the brain and the roots of the cranial nerves. Of these nerves there are twelve pairs. The first pair — the **olfactory nerves** — pass, in the form of many small fibers, from the olfactory lobes to the nose. Tilt the brain to one side and observe the large **optic nerves**, the second pair of cranial nerves, also the **optic chiasma**, from which they spring.

Back of the hemispheres is the broad **pons** with its transverse fibers; it is the ventral portion of the fourth division of the brain, of which the cerebellum is the dorsal portion. Just in

front of it and springing from near the median line may be seen, by tilting the brain to one side, the small **oculomotor nerves**, the third pair of cranial nerves, which pass forward on each side and supply the following muscles of the eyeball: the superior rectus, medial rectus, retractor, inferior rectus, and inferior oblique. From the lateral side of the brain just in front of the pons on each side springs the **pathetic** or **trochlear nerve**, the fourth cranial nerve; it is a delicate strand which passes forward to the superior oblique muscle of the eyeball. It will be seen when the ventral surface of the brain is studied.

The large **trigeminal nerve** — the fifth cranial — springs from the posterior border of the pons by two roots, a small motor and a large sensory root. The large root passes straight forward, and soon enlarges and forms the **Gasserian ganglion**, from which three nerves spring, — the **ophthalmic**, the **maxillary**, and the **mandibular**; the small root joins the last-named nerve. The ophthalmic nerve passes into the orbit, where it gives off branches which go to the eyeball, the upper eyelid, and the nose and snout. The maxillary nerve emerges from the cranium back of the orbit and gives off branches which go to the lower eyelid, the upper lip and jaw, the palate, and the face. The mandibular nerve leaves the cranial cavity back of the orbit and gives off branches which supply the external ear, the muscles of the jaw, the lower jaw, the lips, and the tongue.

Just back of the pons will be seen in the lateral aspect of the brain a swelling called the **trapezium**, which is the anterior end of the medulla. Springing from the medulla medial to the trapezium is the sixth pair of cranial nerves, the **abducens**, which pass to the lateral rectus muscle of the eyeball; these nerves will be seen when the ventral surface of the brain is studied.

Arising from the lateral surface of the trapezium are the **facial** and the **auditory**, the seventh and eighth cranial nerves. The facial is the smaller of the two; it springs from near the base of the trigeminal nerve and passes to the face immediately below the external ear, where it gives off branches which supply the muscles of the face. The auditory is a large nerve just behind the facial, which passes directly to the inner ear.

In exposing the remaining cranial nerves take great care not to break them, as they arise by fine roots which are easily injured.

The ninth and tenth cranial nerves — the **glossopharyngeal** and the **vagus** — arise from the side of the medulla back of the auditory nerve, each by a number of small roots, and leave the cranial cavity together immediately behind the tympanic bulla. The glossopharyngeal passes backward and sends branches to the pharynx and tongue; it is the sensory nerve of the tongue.

The vagus passes along the neck on each side, bound together with the sympathetic nerve, giving off branches to the pharynx and larynx. Two ganglia — the **ganglion jugulare** and the **ganglion nodulosum** — are present in it near the point where it leaves the cranial cavity, the former being in front of the latter.

At the hinder end of the neck the vagus and the sympathetic separate from each other and enter the thorax. The former, which is the larger of the two, soon gives off the **inferior laryngeal nerve**, which runs forward alongside the trachea to the larynx; it then passes to the anterior end of the lung, where it breaks into numerous branches. These form networks about the base of the lungs and the heart, which are called the **pulmonary plexus** and the **cardiac plexus**. Two of these branches pass back, on each side, to the stomach, where they form the **anterior** and the **posterior gastric plexuses.**

The **spinal accessory** — the eleventh cranial nerve — is formed by the union of numerous roots which arise along the lateral surface of the medulla and spinal cord. It passes with the spinal cord into the cranium through the foramen magnum, and then out again together with the vagus and glossopharyngeal nerves; it supplies the muscles of the neck.

The **hypoglossal** — the twelfth cranial nerve — arises from the ventral surface of the medulla by a number of roots. It passes from the cranial cavity to the muscles of the neck and tongue; it is the motor nerve of the tongue.

Exercise 40. Draw a semidiagrammatic view of the lateral aspect of the brain, showing the cranial nerves so far as observed.

Study the ventral surface of the brain. Separate the brain from its attachments and remove it from the body. In taking it out

note the **hypophysis**, a median projection of the ventral surface back of the optic nerves; it is lodged in a depression of the floor of the cranial cavity and may be torn off in removing the brain.

At the anterior end of the hemispheres are the **olfactory lobes**, and back of them, the **olfactory tracts**. Still farther back is a pair of triangular swellings called the **substantia perforata anterior**, because they are pierced by many small blood vessels.

These structures belong to the cerebrum, the anterior division of the brain. Back of them are those which belong to the thalamencephalon, the second division. These are, first, the **optic nerves**, and the **optic chiasma** from which they spring; the chiasma is formed by the meeting of the **optic tracts**, one of which comes from each side. Back of the chiasma is the **tuber cinereum**, a rather extensive median swelling; from it projects the **infundibulum**, which bears at its end the **hypophysis** or **pituitary body**. Just back of the tuber cinereum are two white projections, the **mammary bodies**. On each side of these structures is the large pyriform lobe of the cerebrum.

Back of the mammary bodies are the **pedunculi cerebri**, which belong to the third division of the brain, the midbrain. They are a pair of semicylindrical bodies which proceed from beneath the pyriform lobes backward, converging toward the median line. Between the pedunculi is an area called the **substantia perforata posterior**. The oculomotor nerves spring from this region.

The **pons**, a broad belt of transverse fibers divided in two by a median groove, follows posteriorly; it belongs to the fourth division of the brain. At the anterior border of its lateral ends the delicate trochlear nerves arise.

Back of the pons are the structures which belong to the medulla, the fifth division of the brain. They are the two **trapezia**, one on each side, and in the median area between them a pair of elongated **pyramidal tracts**, which extend far back of them. At the sides of these tracts and behind the trapezia on each side is the **area elliptica**, lateral to which is the **area ovalis**.

Exercise 41. Draw an outline sketch of the ventral aspect of the brain, showing accurately these structures.

Study the internal structure of the brain. The brain, like the spinal cord, is a hollow structure. Unlike the spinal cord, however, in which the cavity is a simple tubular canal, the cavities of the brain form a series of complicated spaces which extend throughout its five divisions and their outgrowths. The brain has thus dorsal, ventral, and lateral walls, which surround these spaces. These walls vary much in thickness in different places, the actual form of the brain being largely due to these variations.

We shall study first a longitudinal median section of the brain. Cut the brain with a large, sharp scalpel, or a razor, into two equal halves by a sagittal incision. Observe the gyri and sulci on the medial surface of the hemisphere. Observe the conspicuous, broad band of white fibers which joins the two hemispheres; this is the **corpus callosum.** Its posterior end is called the **splenium** and is not so thick as the anterior portion. The point where it turns down anteriorly is called the **genu**; the anterior end, which turns slightly posteriorly, is called the **rostrum.** Extending ventrally from the ventral surface of the corpus callosum is a white arched band of longitudinal fibers which is called the **fornix.** In the angle between the anterior half of the corpus callosum and the fornix is the **septum pellucidum.** It is a vertical partition between the two anterior ventricles of the brain, one of which is in each hemisphere. At the ventral end of the fornix is a small band of white fibers called the **anterior commissure,** which extends between the hemispheres. Extending straight ventrally from this commissure is a thin plate, the **lamina terminalis,** which appears in the section as a thin line; it is the forward boundary of the third ventricle of the brain, and bears at its ventral end the optic chiasma.

The **third ventricle,** which is in the second division of the brain, is a very narrow, slitlike space which lies behind the lamina terminalis; if the section be not exactly median, it may not come into view. Its lateral walls are formed on each side by the **optic thalamus.** Ventrally, the ventricle is continued into the tuber cinereum and the infundibulum.

In the dorsal portion of the third ventricle and lying just behind the fornix will be seen the circular cross section of a large body, the **middle commissure**; it joins the two thalami.

The dorsal wall of the third ventricle is a thin membrane which is joined with the vascular pia mater and forms with it the anterior **choroid plexus**; it is situated in the bend of the fornix and may be torn away when the section is made. In the hinder part of the dorsal wall, and just beneath the splenium, is a small conical thickening, the **pineal body** or **epiphysis**.

Back of these structures is the midbrain. The extension of the third ventricle backward into the midbrain is called the **aqueductus Sylvii**; it will be seen to be a straight, longitudinal canal. In its dorsal wall are four thickenings called the **corpora quadrigemina**, which extend back to the cerebellum; its ventral wall is much thicker than the dorsal, and forms the **pedunculi cerebri**, which extend back to the **pons**.

The fourth and fifth divisions of the brain are behind the midbrain. Their cavity is the **fourth ventricle**, which extends back from the aqueductus Sylvii and is continuous posteriorly with the central canal of the spinal cord. This ventricle is narrow at its two ends and wide in the middle. The dorsal wall, which is just beneath the cerebellum, will be seen to be very thin, and is often torn away by the knife in making the section. The hinder portion of it is joined with the vascular pia mater and forms the posterior **choroid plexus**.

The cerebellum is an outgrowth of the dorsal wall of the fourth division of the brain. The peculiar branching of its numerous folds, especially of the white matter as it appears in a longitudinal section, has received the name of the **arbor vitæ**. Note the great thickness of the pons which forms the ventral wall of this division of the brain.

Exercise 42. Draw the median surface of the divided brain and carefully label all of the parts which appear.

The lateral ventricles. The two hemispheres contain the first and second, or lateral, ventricles and are bound together, as we have seen, by the corpus callosum and the fornix. Introduce

the blade of a small scalpel between the upper surface of the corpus callosum and the hemisphere of the left half of the brain, and remove the hemisphere, being careful not to cut into the ventricle, the roof of which is formed by the corpus callosum. Now cut through the corpus callosum into the ventricle and carefully chip away the entire roof of the latter, but do not remove the fornix. The cavity is thus fully exposed; its anterior end is called the **anterior horn**, the posterior portion the **inferior** or **posterior horn**. The former passes ventrally and ends near the medial plane in the anterior portion of the hemisphere; the latter is a long, narrow passage, semicircular in form, which lies in the posterior lobe of the hemisphere and parallel to its outer surface.

The floor of the anterior horn projects into the cavity and is called the **corpus striatum**. The floor of the posterior horn likewise projects prominently into the cavity and is called the **hippocampus**. Along the entire anterior border of the hippocampus is a band called the **fimbria**, which is covered by a vascular membrane.

The **fornix**, as we have already seen, is a narrow, median band of longitudinal fibers which lies between the hemispheres just below the corpus callosum. It consists of several parts, which cannot be observed if the section be not exactly median. Its forward end is split, forming the anterior **pillars of the fornix**, which are medial to the corpus striatum. Just behind the pillars, and between them and the middle commissure, is the **foramen of Monro**, a small opening which joins the two ventricles of the hemispheres with the third ventricle. The posterior portion of the fornix is also split, forming the posterior **pillars**, which lie medial to the hippocampi of the hemispheres. The fornix, the hippocampus, and the fimbria, it will be seen, lie in the ventral wall of the hemisphere and immediately in front of and dorsal to the third ventricle.

Exercise 43. Draw a sketch showing these structures.

Carefully remove the hippocampus and the fimbria. Beneath them are two oblique ridges, — the paired **optic thalami**, — which

form the sides of the thalamencephalon, and between which is the third ventricle. Each thalamus extends laterally and ventrally to the ventral side of the brain, where it becomes the **optic tract**; the two optic tracts form the optic chiasma from which the optic nerves proceed.

Back of the optic thalami are the **corpora quadrigemina**, two pairs of elevations which belong to the midbrain. The anterior are somewhat smaller than the posterior.

Remove the cerebellum. The roof of the **fourth ventricle** will now be seen, the presence of which is marked by a large triangular depression. The prominent ridge on each side of the ventricle is the **area ovalis**.

Exercise 44. Draw a sketch showing these structures.

The spinal cord. Remove the skin and muscles from the vertebræ of the neck and trunk. With bone forceps remove the roof of the neural arches of all the vertebræ and expose the spinal cord. Note the spinal nerves issuing from the invertebral foramina, and their dorsal and ventral roots. Observe also the ganglion in the dorsal root, and the two rami of the nerve. Note the enlargement of the cord in the cervical and the lumbar region. Posteriorly the cord diminishes in size until it becomes a small strand called the **filum terminale**, which goes into the tail. In the sacral and caudal regions the spinal nerves are small and pass almost directly backward. They lie thus close together and form, with the filum terminale, a bunch of fibers called the **cauda equina**. On both the dorsal and ventral sides of the spinal cord a median longitudinal fissure is present.

Exercise 45. Draw an outline of the dorsal surface of the cord.

Make a cross section of the cord and note the inner gray and the outer white matter, the small central canal, and the dorsal and ventral fissures.

Exercise 46. Draw the cross section.

The muscular system. Kill a cat as directed at the beginning of this dissection and skin it. The cutaneous muscles will be

removed with the skin. These are two in number, the **great cutaneous** and the **platysma**. The former is a very broad, thin, transparent muscle, which extends beneath the skin over almost the entire side of the body. The latter covers the sides and back of the neck and the sides of the head.

Study first the superficial muscles of the side of the body. Remove the fat which may overlay any of these muscles. Note the broad white membrane which covers the back in the abdominal region: this is the **lumbodorsal fascia**. Note also the narrow white membrane in the midventral area: this is the **linea alba**.

On the side of the trunk between the fore and hind legs two large muscles occupy almost the whole space, the **external oblique** and the **latissimus dorsi**. The former is a thin plate which covers the lateral and ventral portions of the abdomen. It arises from the last nine or ten ribs and the lumbodorsal fascia and extends ventro-posteriorly to the midventral portion of the abdomen. The latter is a broad muscle which arises from the neural processes of the posterior nine thoracic and the anterior six lumbar vertebræ, and passes over the dorsal portion of the anterior end of the external oblique to the forearm and shoulder, where it is inserted in the medial surface of the humerus. It draws the arm back.

Immediately anterior to this muscle on the dorsal side of the trunk are the trapezius muscles. The posterior trapezius, or **spinotrapezius**, arises from the neural processes of the thoracic vertebræ and passes to the spine of the scapula. The middle trapezius, or **acromiotrapezius**, lies in front of the last-named muscle and directly above the scapula. It arises along the middorsal line of the neck and shoulder and passes to the spine of the scapula. The anterior trapezius, or **clavotrapezius**, arises from the posterior surface of the skull and the middorsal line of the neck and extends downward along the sides of the neck to the clavicle, where it is continuous with the **clavobrachial**, a muscle which extends ventrally to the ulna.

Ventral to the middle trapezius is the **spinodeltoid muscle**, which extends from the spine of the scapula to the anterior side of the humerus. Between the last-named two muscles and the anterior

trapezius are the **acromiodeltoid** and the **levator scapulæ**, the latter being dorsal to the former.

In front of the anterior trapezius on the side of the neck is the **sternomastoid muscle**, whose function is to turn and depress the head; it extends from the skull back of the external ear to the breastbone.

On the side of the head are two prominent muscles, the **masseter** and the **temporal**, whose function is to close the lower jaw. The former lies below and back of the eye; the latter is a large fan-shaped muscle which covers the side and top of the head back of and above the eye, and extends to the lower jaw.

On the proximal division of the fore leg are seen two large muscles, the lateral and the intermediate portions of the **triceps**; they are inserted by a broad tendon in the olecranon process of the ulna. The intermediate portion extends from the scapula and forms the hinder border of the upper arm; the lateral portion extends from the proximal end of the humerus and forms its lateral surface.

On the proximal division (the thigh) of the hind leg are seen the **sartorius muscle**, which forms its anterior border, and the **biceps femoris**, a large muscle which forms its middle and hinder portion. Between them is the membranous **fascia lata**.

Exercise 47. Draw the lateral aspect of the animal and place in it the outlines of these muscles, showing the direction of their fibers. Carefully label all.

Study the muscles of the ventral aspect of the trunk and legs. Covering the abdomen are the paired **external oblique muscles**, which have already been described. In the region of the breast are the **pectoral muscles**. These constitute a group of four large muscles, more or less connected with one another, which extend from the sternum to the humerus and pull the fore legs backward and medially. In front of the anterior pectoral is the **clavobrachial**, which we have already seen; its dorsal continuation, the **clavotrapezius**, appears on the side of the neck. Medial to the last-named muscle is the **sternomastoid**.

On the upper arm the posterior border is formed by the intermediate portion of the **triceps**; the ventral portion is formed by the **biceps brachii**, which extends from the scapula to the humerus.

On the hind leg two prominent muscles appear on the inner side of the thigh, — the **sartorius** which forms its anterior and the **gracilis** which forms its posterior portion.

Exercise 48. Draw the ventral aspect of the trunk and place in it outlines of these muscles, showing the direction of their fibers. Carefully label all.

Beginning with those of the hind legs, dissect out each of the muscles that has been observed; completely free it from the abutting organs and find its origin and insertion. Do not, however, disarticulate or injure any of the bones. While studying the external oblique muscle note that the abdominal wall is composed of the following muscles: the **external oblique** on the outside; the **internal oblique** just beneath it, the fibers of which run at right angles to the fibers of the external oblique; the **rectus abdominis**, a long narrow muscle which, with its fellow, extends in the midventral area from the pubis to the ribs, and lies between the aponeurosis of the two obliques anteriorly and dorsal to both posteriorly; and the **transversus muscle**, which lies next to the abdominal cavity, the fibers of which have a transverse direction.

The skeletal system. This is made up of two portions, — the **exoskeleton** and the **endoskeleton**. The former consists of certain special integumental structures, — the hair, claws, and teeth. The **hairs** are epidermal structures which form a protective covering against cold and external injuries. They are also to a certain extent tactile organs. The **whiskers**, or **vibrissæ**, are enlarged hairs, the principal function of which is sensory. The claws are horny epidermal structures and are closely allied to hairs. The teeth have a twofold origin: the dentine is a dermal structure, being modified dermal bone, and the enamel an epidermal structure, arising as a secretion of epidermal cells.

The **endoskeleton** is the bony and cartilaginous framework of the body. It may be divided into the **axial skeleton**, which includes the skull and the vertebral column, together with the ribs and the sternum, and the **appendicular skeleton**, which includes the framework of the extremities.

To prepare the internal skeleton for study, open the abdominal cavity, without injuring the sternum or ribs, and remove all the viscera. Cut away the diaphragm and remove the heart and lungs and other thoracic organs. Remove the greater part of the muscles which still remain in the body, being very careful not to injure the bones.

The body, thus prepared, should be boiled until the bones can be thoroughly cleaned. It is well while doing this to disarticulate the head and the hind limbs from the remainder of the skeleton. Do not, however, boil the bones until the ligaments are destroyed and the bones fall apart. It is also well to pass a string through the neural canal as soon as the spinal cord is destroyed, and tie the two ends together so as not to lose the sequence of the vertebræ, and to number the ribs.

The appendicular skeleton. The **anterior extremities** are made up of the pectoral girdle and the fore legs. The **pectoral girdle** is a paired structure which in most land vertebrates is made up, on each side, of the scapula, coracoid, and procoracoid or clavicle. In the cat it is very incomplete, the dorsal element, the **scapula**, being the only one which is well represented. This is a flat, triangular bone, which lies between the muscles and the ribs near the anterior end of the thorax, on each side. Projecting from the middle of the lateral surface is a flat ridge called the **spine** of the scapula, which divides this surface into two areas, — the **supraspinous fossa** which lies anterior and the **infraspinous fossa** which lies posterior to the spine. Ventrally the spine bears two processes, — the **acromion process** near the ventral end and the **metacromion process** dorsal to it. At the ventral end of the scapula is a depression called the **glenoid fossa**, in which the humerus articulates. Near the anterior end of this fossa is a curved projection, the **coracoid process**, which is homologous to the coracoid bone of the lower vertebrates.

Besides the scapula the pectoral girdle contains, on each side, the **clavicle.** This is a small curved bone which lies imbedded in the muscles of the shoulder. It does not articulate with any other bone but is joined with the acromion process by a ligament.

Exercise 49. Draw the lateral side of the scapula.

The skeleton of the **fore leg** is made up of three divisions, — a proximal, a middle, and a distal division. The **proximal division** is formed of the **humerus**, a large cylindrical bone. At its upper end are two prominences, of which the outer one is the **greater tuberosity** and the inner is the **lesser tuberosity** of the humerus. Along the anterior side near its upper end is an elevation called the **deltoid ridge.** Near the lower end is an opening in the bone, — the **supracondyloid foramen**; and a deep depression — the **olecranon fossa** — is present on the hinder side.

The **middle division** of the leg is formed of the **radius** and the **ulna,** which articulate with the distal end of the humerus. The ulna is the hindermost and the larger of the two bones, and possesses at its proximal end the large **olecranon process** which articulates in the olecranon fossa of the humerus and forms the elbow. The articular surface of the ulna with the humerus is formed by the **semilunar notch,** a deep depression just back of the olecranon process. The radius is preaxial in position, being in front of the ulna. Note carefully its relation to the ulna and to the bones it articulates with at both ends.

The **distal division** of the fore leg is formed by the **carpus** or wrist and the **manus** or hand. The carpal bones are seven in number, arranged in two rows, three being in the proximal and four in the distal row. The hand is composed of the **metacarpal bones** and the **digits.** The metacarpals are five in number, of which the first is the shortest. The digits also number five, each one being composed of a number of bones called **phalanges.** The first digit, which corresponds to the thumb, is composed of two phalanges; the others have three apiece.

Exercise 50. Make a drawing showing all the bones of the leg. Carefully label all.

The **posterior extremities** are made up of the pelvic girdle, or pelvis, and the hind legs. The **pelvic girdle** is formed by two bones, the right and left **innominate bones**, which together form an arch. This arch articulates dorsally with a portion of the spinal column called the **sacrum**; ventrally the two innominate bones meet and unite in the midventral line, this union being called the **symphysis pubis**. In the middle of the lateral surface of each innominate bone is a circular depression, called the **acetabulum**, in which the femur articulates. A large hole, called the **obturator foramen**, is present in the ventral half of the bone. The innominate bone is formed by the union of four bones, — the **ilium** which forms its dorsal portion, the **ischium** and **pubis** which form its ventral, and the **acetabular**, a small bone between the other three, which forms a part of the acetabulum. The ilium articulates with the sacrum; the ischium and the pubis are separated by the obturator foramen, the former being the larger and more posterior of the two. In most land vertebrates the pelvic girdle is composed of three bones, — the ilium, pubis, and ischium.

Exercise 51. Make a drawing of the lateral aspect of the innominate bone.

The skeleton of the **hind leg** may be divided into a proximal, a middle, and a distal division. The **femur** or thigh bone forms the **proximal division**; it is a cylindrical bone, at the upper end of which is the **head**, which articulates in the acetabulum. At the side of the head is a large protuberance called the **great trochanter**; distally the bone ends in two projections, — the **condyles**.

On the anterior side of the distal end of the femur is a small independent membrane bone which develops in a tendon and forms the kneepan; it is called the **patella**.

The **middle division** of the leg is formed by the **tibia** and **fibula**. The tibia is the larger and longer of these bones and alone articulates with the femur. Carefully note the relation of these two bones with each other.

The **distal division** is formed by the **tarsus** or ankle and the **pes** or foot. The tarsal bones are seven in number. The largest

is the **calcaneum** or heel bone; the large bone which articulates with the tibia is the **astragalus.**

The skeleton of the foot is composed of five **metatarsal bones** — of which the first is rudimentary — and four **digits** or toes. Each digit has three **phalanges.** The first digit is wanting; the one opposite the calcaneum is the fifth.

Exercise 52. Make a drawing of the bones of the hind leg, reproducing the outlines of each exactly.

The axial skeleton. The **vertebral column** consists of a succession of disklike vertebræ which are closely joined with one another by intervertebral ligaments; thin cartilaginous disks also lie between them. The column may be divided into a number of regions, there being seven **cervical**, thirteen **thoracic**, seven **lumbar**, three **sacral**, and a variable number of **caudal** vertebræ.

Each **vertebra** is a single bone, which has been formed by the fusion of several distinct bones. The body of the vertebra, or **centrum**, forms its ventral portion. The **neural arch**, which incloses the neural canal and is dorsal in position, is composed originally of three bones, — the two lateral **neural processes** and the median **neural spine** or **spinous process.** Extending laterally or ventrolaterally from the centrum and neural process on each side is the **transverse process.** Projecting from the anterior and also from the posterior surfaces of the neural processes are articular processes by which the vertebræ are firmly fitted together. These are the **zygapophyses.** The anterior or **prezygapophyses** project at the anterior end of a vertebra and articulate with the posterior or **postzygapophyses** of the vertebra in front of it. Between the neural processes of each two vertebræ on each side is an opening called the **intervertebral foramen,** through which the spinal nerve passes.

The **cervical** vertebræ are not all alike. The first two are called the atlas and axis, and support the skull. The **atlas** is a bony arch which consists of a ventral and two lateral portions, — the latter being the broad transverse processes. A centrum and a spinous process are absent. Note the two surfaces which articulate with the occipital condyles of the skull; note also the

postzygapophyses. Two foramina will be seen on each side, the **foramen transversarium** at its hinder and the **atlantal foramen** at its forward end; note the groove which joins them; these structures form the anterior end of the vertebrarterial canal. The **axis** has a high and much elongated spinous process and its centrum is continued anteriorly as a conical projection called the **odontoid process.** This process projects into the atlas, whose centrum it represents, where it is held in position by the **transverse ligament.**

The transverse processes of the cervical vertebræ are not homologous to those of the other vertebræ, but each is equivalent to a transverse process plus the rudiment of a rib. Between this rib-rudiment and the transverse process is a round hole, the **foramen transversarium.** Note the shape of the transverse processes in the different cervical vertebræ. The dorsal portion in each case represents the transverse process proper; the ventral portion represents the rib-rudiment, and in the sixth vertebra is double. In the seventh vertebra these ribs, and consequently the foramina transversaria, are usually absent. The **vertebrarterial canal** is formed by the succession of the foramina transversaria on each side, and contains the vertebral artery and vein.

The **thoracic vertebræ** are distinguished by their very long spinous processes and by the ribs which articulate with them. Observe their zygapophyses. Thirteen pairs of **ribs** are present, the dorsal portion of each being bone, the ventral portion being cartilage. The nine anterior pairs of ribs articulate separately with the sternum; the last three or four pairs are united with one another ventrally, and the ventral ends of the thirteenth pair are free. All of the ribs except the last two or three pairs articulate dorsally by two surfaces each; the **capitulum,** or head of the rib, articulates with the centrum of two contiguous vertebræ, and the **tuberculum** articulates with the transverse process. The tuberculum is absent on the last two or three ribs.

The **sternum,** or **breastbone,** is a row of bones which lies in the ventral wall of the thorax and forms the ventral support of the ribs. The foremost of these bones is the **manubrium**; the hindermost is the **ensiform process,** the posterior part of which is cartilaginous.

The **lumbar vertebræ** are larger than the thoracic; they are distinguished by the large size of the transverse processes, which are directed backward and downward.

The **sacral vertebræ** in the adult form a single bone called the **sacrum**. The two innominate bones which form the pelvis are closely joined with it. Note the two **intervertebral foramina** on each side of it.

The **caudal vertebræ** become gradually smaller toward the hinder end, the last ones consisting of centra only. A number of caudal vertebræ near the forward end of the tail bear each a pair of short ventral processes called the **hæmal processes**; the space between the two members of each pair is closed by a small median **chevron bone** and contains the caudal artery and vein.

Exercise 53. Draw the following views: the anterior end of the atlas, the lateral aspect of the axis, and the anterior end of the sixth cervical vertebra, on a scale of 2 or 3.

Exercise 54. Draw the anterior end of the fourth thoracic vertebra; also the lateral aspect.

Exercise 55. Draw the anterior end and also the lateral aspect of the fourth lumbar vertebra.

Exercise 56. Draw the ventral surface of the sacrum.

Exercise 57. Draw a ventral view of the fourth caudal vertebra; also one of the last caudal vertebra.

The skull. The skull is made up of two portions, the **cranium** and the **visceral skeleton**. The former protects the brain and the organs of special sense, and the latter forms the framework of the greater part of the face, the jaws, and the tongue.

Observe the general character of the skull. Note the **sutures** by which the bones are joined with one another; they are the growing surfaces, and in an old animal tend to become obliterated by the fusion of the bones. Of the animals studied in this course, only the turtle has such a compact and strongly built skull. The **teeth**, although they are integumentary structures,

are sunk into deep depressions in the bones of the jaws and are so firmly joined with them that a very solid biting surface is formed.

On each side of the skull is the large **orbit**, in which the eyeball and its muscles, glands, and other accessory organs are contained; the prominent ridge over it is the **supraorbital ridge**. The orbit is not complete, as in man, but is open behind and at the side. Just behind it and communicating with it is a depressed area called the **temporal fossa**. The prominent arch on the side of the skull, forming the lateral boundary of the orbit and the temporal fossa, is the **zygomatic arch**. The large temporal muscle which helps to close the mouth arises on the surface of the temporal fossa.

In the hinder end of the skull is the **foramen magnum**, a large circular opening through which the spinal cord enters the brain cavity. The prominent transverse **lambdoidal ridge** marks the dorsal border of the hinder end, from the middorsal point of which the **sagittal ridge** runs forward. On either side of the foramen magnum are the **occipital condyles**, a pair of protuberances which articulate with the atlas. At the side of the skull just back of the zygomatic arch is the **external auditory meatus**, the outer opening of the ear. At the anterior end of the skull are the **nasal capsules**, the walls of which are partly cartilaginous; the openings in their forward end are the **anterior nares**.

On the ventral surface of the skull on each side is the prominent rounded **tympanic bulla**, which contains the middle ear. Between the orbits is the opening of the **nasopharynx**. Just back of the incisor teeth are two large openings, the **foramina incisa**. Note the articulation of the lower jaw.

Study the bones of the skull as they appear on the dorsal, the lateral, and the ventral surfaces.

The bones of the **cranium**, as already suggested, fall into two categories, — those of the **cranium proper**, or brain case, and those of the **special sense capsules**. Those belonging to the brain case occupy the central portions of the skull. The organs of hearing, sight, and smell are lodged, in the embryo, in protective membranous or cartilaginous capsules; in the adult, certain

bones have developed in these capsules, which form an intimate union with the brain case. The auditory capsule has undergone the most complete ossification, the bones present in the adult forming the side of the skull back of the orbits. The optic capsule does not ossify, but a membrane bone, the lachrymal, appears at its anterior end. The orbit, in which the eye lies, is formed of the bones of the brain case and the visceral skeleton. The nasal capsules are bony and cartilaginous, and form the forward end of the skull.

The bones of the **visceral skeleton** fall readily into three categories, according to their position, — those of the upper jaw and upper part of the face, those of the lower jaw, and those of the tongue.

The dorsal and posterior aspects. The hinder end of the skull is formed of a single bone, the **occipital**, which has been formed by the fusion of four bones, — the ventral **basioccipital**, the two **exoccipitals** which bear the two occipital condyles, and the dorsal **supraoccipital.**

In the dorsal aspect the small **interparietal bone** forms the median portion of the lambdoidal ridge. In front of this ridge are the large paired **parietal bones**, and in front of them the large paired **frontal** and the paired **nasal bones**, the latter lying at the anterior end of the skull. These bones are all membrane bones and form the roof of the skull.

Lateral to each parietal is the large **temporal bone** which contains the auditory organ. Projecting forward from it is the large **zygomatic process** which forms the hinder part of the zygomatic arch.

On each side of the nasals is the **maxillary bone**, and in front of them are the two **intermaxillary bones**; these two pairs of bones bear the teeth. Projecting backward from the maxillary on each side is its **zygomatic process**, which forms the anterior portion of the zygomatic arch. The middle portion of the arch is formed by the **malar bone.** Extending from this bone medially and dorsally is its **frontal process**, which almost meets the **zygomatic process** of the frontal bone, and separates the orbit from the temporal fossa.

Between the maxillary and frontal bones in the orbit is the small **lachrymal bone.**

Exercise 58. Draw a view of the dorsal aspect of the skull, with the outlines of the bones which appear.

The lateral aspect. The **temporal bone** is here seen in its entire extent. It is made up of three principal portions, — a dorsal expanded **squamous portion**, which bears the zygomatic process; a **tympanic portion**, which forms the tympanic bulla, and in which is the external auditory meatus; and a **petrous portion**, which is the hinder and inner part and contains the inner ear. Just back of the external auditory meatus is the **stylomastoid foramen**, for the passage of the facial nerve, beneath which is a deep pit resembling a foramen. Just in front of this foramen are four foramina in a row, the one nearest it being the **foramen ovale**, for the passage of the mandibular branch of the trigeminal nerve; the next one, the **foramen rotundum**, for the passage of the maxillary branch of the trigeminal: the next, the **orbital fissure**, for the passage of the oculomotor, trochlear, and abducens nerves, and the ophthalmic branch of the trigeminal; and the anterior one, the **optic foramen**, for the passage of the optic nerve.

In the anterior margin of the orbit are two foramina, the dorsal and smaller one being the **lachrymal foramen**, through which the nasolachrymal duct passes to the nose; the ventral one being the **infraorbital foramen**, through which an artery and a branch of the maxillary nerve pass from the orbit to the face. A short distance back of these are two foramina close together, — the **sphenopalatine foramen**, the larger one, and the **palatine foramen**, through which small arteries and nerves pass.

Exercise 59. Draw a view of the lateral aspect.

The ventral aspect. In front of the occipital is the **basisphenoid bone**, and in front of that the small **presphenoid**. The paired lateral projections of the former are homologous to the alisphenoids of lower vertebrates; a pair of processes projecting ventrally in front of these are the **pterygoid processes**, which are homologous to the parasphenoid bone of lower vertebrates. The

paired **lateral** projections of the presphenoid are homologous to orbitosphenoid bones. In front of the presphenoid are the paired **palatine bones**, which form the hard palate. In the base of the zygomatic process of the temporal bone is the **glenoid cavity**, in which the lower jaw articulates.

In addition to the foramina already mentioned the large **foramen jugale** and the **hypoglossal foramen** will be seen. The former is a large hole between the tympanic bulla and the occipital bone through which the glossopharyngeal, vagus, and spinal accessory nerves pass; the latter is in the hinder margin of the former.

Exercise 60. Draw a view of the ventral aspect.

With a fine saw divide the skull into two slightly unequal halves by a longitudinal dorsoventral incision just at one side of the median line, and study its inner surface. The interior of the skull is divided into three cavities, — the cranial, the auditory, and the nasal cavities, which contain the brain, the auditory, and the olfactory organs, respectively.

The **cranial cavity** is further subdivided into the **cerebellar, cerebral,** and **olfactory fossæ.** The first of these occupies the hinder part of the skull, being bounded anteriorly by the **tentorium,** the transverse partition extending inward from the parietal bones. In the floor of this cavity is the **internal auditory meatus,** a large depression divided by a partition into two parts, the dorsal part containing the foramen of the facial nerve, the ventral part containing a number of small foramina of the auditory nerve. Beneath this meatus is the **hypoglossal foramen,** posterior to which is the **condyloid canal,** through which a vein passes.

The **cerebral fossa** is the largest of the three; it occupies the entire central portion of the cranial cavity. In its floor is the large **optic foramen,** just back of which is a large circular depression, the **sella turcica,** in which the hypophysis lies.

The **olfactory fossa** occupies the anterior end of the cranial cavity and lies beneath the frontal bones. Its anterior end is bounded by the **ethmoid bone,** in which the **mesethmoid portion,** the **labyrinths,** and the **cribriform plate** may be distinguished. The

mesethmoid, the median portion, is a vertical plate which separates the nasal capsules from each other; the cribriform plate is a transverse perforated bone which forms the anterior wall of the brain cavity and gives passage to the fibers of the olfactory nerve into the nasal capsules; the labyrinths are folded bony plates which are attached to the cribriform plate on each side and form the turbinals of the nasal capsules.

The **nasal cavity** occupies the anterior end of the skull. It is divided into a right and a left nasal cavity by the vertical mesethmoid bone, while the hinder wall is formed by the cribriform plate. The floor of the nasal cavities is formed by the paired **palatine bones** and its roof by the paired **nasal bones.** The **vomer** is a narrow bone which lies along the ventral edge of the mesethmoid and helps form the nasal septum. The hinder part of each cavity is divided by a horizontal ridge of the vomer into a dorsal and a ventral compartment. The latter is the smaller and is the respiratory part of the nose; the former is the olfactory part. Note the **anterior** and **posterior nares.**

The **auditory cavity** of the skull has already been studied.

Note the **frontal** and the **sphenoidal sinuses,** open spaces in the frontal and presphenoid bones; they communicate with the nasal cavity.

Exercise 61. Draw a view of the section of the skull showing these cavities and the boundaries of the bones forming them.

Of the bones just studied, the following belong to the **cranium proper,** or brain case: the occipital, basisphenoid, presphenoid, and ethmoid, all of which are cartilage bones and form its base; and the parietals and frontals, which are membrane bones and form its roof. The **special sense capsules** are three in number. The **auditory capsule** is lodged in the temporal bone. As we have seen, this bone is made up of three parts, — the petrous, tympanic, and squamous portions. The petrous part, which contains the inner ear and is a cartilage bone, is formed by a fusion of the proötic, epiotic, and opisthotic bones, — these bones being in many lower vertebrates distinct and separate. The

tympanic portion, which contains the middle ear, is a membrane bone. The squamosal is also a membrane bone; it forms a part of the wall of the brain case. The **optic capsule** does not ossify, but the lachrymal is a membrane bone which develops in connection with it. The **nasal capsule** is formed by the ethmoid, the nasals, and the vomer, — the ethmoid alone being a cartilage bone.

The bones of the **visceral skeleton** which enter into the formation of the upper jaw and the upper part of the face are the maxillaries, premaxillaries, malars, and palatines.

The **lower jaw**, or **mandible**, is a single bone which is composed of a right and a left half, joined in the median line. At the proximal end of each half are the **condyle**, which articulates in the glenoid cavity of the temporal bone, and the **coronoid process**, which projects dorsally and in which the temporal muscle is inserted. Just in front of the condyle is the **inferior dental foramen**, through which a branch of the mandibular nerve enters the bone.

Exercise 62. Draw a view of the medial aspect of the mandible.

The **hyoid apparatus** has already been studied (see page 245).

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